NAALAKKERSUISUT
GOVERNMENT OF GREENLAND

OXFORD GLOBAL PROJECTS

RISK ASSESSMENT OF SISIMIUT–KANGERLUSSUAQ ROAD PROJECT

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Executive Summary

Introduction and objectives: The Sisimiut–Kangerlussuaq Road Project, also known as the Arctic Circle Road, is a proposed 170km Arctic road connecting Sisimiut to Kangerlussuaq in Greenland. At an expected budget of DKK 300-650 million, the Arctic Circle Road represents an ambitious undertaking. Both the Government of Greenland and Qeqqata Municipality are currently involved in the road planning, but the financial arrangements, including cost sharing, have not yet been agreed.

To support decision-making, the Government of Greenland contracted Oxford Global Projects (OGP) to undertake an independent risk assessment of the Arctic Circle Road. The objectives of this risk assessment were to: i) review the business case, ii) provide an objective and independent review of the project risks associated with its cost, schedule and benefits, and iii) make recommendations for the future of the project.

In the following executive summary, the key findings and recommendations are presented before a more detailed overview is given.

Key findings and recommendations:

1. There is sufficient supporting evidence from the stakeholder interviews, case studies, and literature to conclude that the primary tourism benefits presented in the business case are plausible. The investment is also likely to satisfy a local need.
2. Other benefits including associated investment, lower cost of living, and enabling science and research are also supported. But currently, the economic appraisal focusses narrowly on tourism benefits.
3. In general, the assumptions that are required to hold for benefits to be realized appear to largely be in place. Potential demographic change in Kangerlussuaq is unlikely to affect the benefits-to-cost ratio of the socio-economic analysis appraised due to the almost exclusive focus on tourism derived benefits.
4. Based on our statistical analysis, we find that the Arctic Circle Road is likely to achieve a positive benefit-to-cost ratio, even under a conservative scenario. In comparison with OGP's

large data sample on benefit performance from 793 roads projects, the Arctic Circle Road can bear to be in the worst 9-15% of road benefit shortfalls while still maintaining a positive benefits case.

5. The quantitative cost and schedule risk assessments of Arctic road projects show a need for budget and schedule uplifts on top of the base estimates depending on the risk appetite of decision makers.
6. While the cost estimates may be out of date and not reflect a single preferred route option, our cost sensitivity analysis shows that much higher construction costs can be tolerated and still maintain a positive business case, thus this uncertainty is unproblematic.
7. However, the project design and development require further work before a final decision should be made. At present, the design of the road is very immature and needs to be developed to better understand uncertainties.
8. Further investigations, design and preparatory works are required to determine and detail a single preferred option for the route and better understand construction challenges and opportunities. Once this is agreed, the cost estimates should be updated.
9. If the updated estimates are considered affordable, an updated business case, including validation of potential investments and revenue benefits, would be required.
10. Further, decisions around regional investment strategies, cost sharing, and risk appetite are also required to advance the project towards a final decision.
11. Progression of the project and realisation of benefits is contingent on alignment of interests among the key stakeholders. This will require strategic dialogue among key high influence stakeholders.
12. A decision over the next stage of the project is likely to provide the signal of intent required to foster investment commitment and dialogue among these stakeholders.
13. Our combined findings support a decision towards further advancement of the project, which at this stage would involve further investigations required to determine and detail a single preferred option for the route.

Methodology: Reference class forecasting (RCF) was used to determine the quantitative risk of the project experiencing cost and schedule overrun and benefit shortfall in comparison to the 3 base estimates and the socio-economic analysis found within the business case provided by Qeqqata Municipality. Data from the OGP database were used to build an international reference class of roads completed all over the world (cost n=977, schedule n=340, benefit n=793). A reference class of Arctic roads was also constructed (cost n=16, schedule n=14). Due to the limited sample size and granularity of data available for Arctic roads, a literature review of arctic-specific cost and schedule drivers and risks of overrun and benefit shortfall was conducted. This was used to hypothesise likely causes of the overruns and shortfalls identified in the RCF.

It was only possible to establish the quantitative risk of benefit shortfall using the international reference class of roads because data on Arctic road benefits was not available. To better understand the potential risks to Arctic roads realizing expected benefits, as well as appraise the Arctic Circle Road business case from an in-depth stakeholder perspective, a qualitative deep dive was carried out. This included reviewing case studies of road investments in other Arctic countries and semi-structured interviews with stakeholders of the Arctic Circle Road (30 interviews with 12 stakeholder groups).

Results: The literature review found that Arctic roads are likely to have a heightened risk profile when compared to roads built in more temperate regions. The main drivers of cost and schedule overrun for Arctic roads are: complying with environmental regulations, enhanced community consultation and environmental impact assessment, inefficiencies caused by extreme working conditions, high drainage costs, high transport costs, disproportionate direct and indirect labor costs, difficult to predict material costs, requirement for extensive surveys to reduce risk, and high maintenance costs that will increase as climate change worsens. The key areas susceptible to benefit shortfall are: socio-economic benefits, road use, and environmental impact.

It should be understood that the authors are not stating that Arctic roads are high risk infrastructure projects; just that they carry more risk than building roads in temperate regions. For context, Arctic roads carry less risk than all other types of major arctic transport infrastructure projects – i.e., airports, ports, railways, and fixed links.

For the quantitative cost risk assessment, we found no statistically significant difference in the cost risk profiles of roads built in Arctic regions and roads built elsewhere. However, we took a conservative approach and assumed that Arctic roads may carry more risk than our international reference class of roads. This was because the literature review suggested that Arctic road construction carries more risk than in temperate regions, and because our limited sample size for the statistical tests (n=16) may mean that a significant difference was present but not detectable. Accordingly, we constructed an Arctic road specific reference class in addition to our international road reference class. A tailored reference class for the Arctic Circle Road was also created based on the cost breakdown of the Rambøll cost estimate for the road construction. This tailored reference class includes a cost uplift, which we call the *Arctic premium*, which is the calculated cost risk discrepancy between arctic and non-arctic road projects based on RCF data.

The two reference class approaches show a similar level of risk for the Arctic Circle Road. A P50 level of certainty that the project will complete within budget (50% chance of cost overrun) requires a budget uplift of 9-14%, while a P70 level of certainty (30% chance of cost overrun) requires a budget uplift of 33-44%. These budget uplifts apply to the contingency-free base estimate for road construction, thus any contingency allocation for unforeseen costs, risk or inflation should be stripped from the estimate before RCF uplifts are applied. This is important to note, since it is unclear how much contingency is included in the current construction cost estimates.

A limitation to these findings is that the sample size for Arctic roads was at the lower bound of the number of projects required for a robust reference class. However, we have confidence in the conclusions because both reference class approaches – with one being based on several thousand projects from the OGP dataset – show similar risk profiles for the Arctic Circle Road. Additionally, the statistical analyses found no difference in the cost risk profiles of arctic and non-arctic road construction, which normally would point to pooling the data and utilising the international roads reference class. **Therefore, the Arctic road reference classes should be seen as a conservative measure in that they display higher risk than the statistical analysis would indicate.**

The cost sensitivity analysis shows that the business case is robust in that much higher construction costs can be tolerated while still maintaining a positive business case. The cost estimates may be out of date and will require updating after further surveys and investigations are completed, but the sensitivity analysis shows enough headroom for considerable cost increases, thus this is not thought to jeopardize the business case.

The quantitative schedule risk assessment of Arctic road projects shows that half of the Arctic road projects had a schedule overrun of equal to or less than approx. 9%, while half of roads overall had a schedule overrun of equal to or less than 11%. This means that a P50 level of certainty of avoiding a schedule overrun requires a schedule uplift of 9%. A P70 level of certainty (30% chance of schedule overrun) requires a schedule uplift of 27%. The schedule risk profile of Arctic road projects is overall very similar to that of normal road construction, and we recommend that the Arctic Circle Road uses the international distribution of road schedule overruns for its planning.

The quantitative benefits risk assessment using the much larger international reference class shows that 50% of road projects (P50) experience a benefit shortfall of 8% or less, and 70% of projects (P70) experience a benefit shortfall of 24% or less. A sensitivity analysis of the benefits case in the socio-economic analysis found the benefits-to-cost ratio was still positive with 41% less benefits for Scenario A, which equals a P85 in the reference international reference class, and 53% less benefits for Scenario B, which equals a P91 in the international reference class. **This means that the Arctic Circle Road would only have to perform better than 9-15% of all road projects to maintain a positive benefits case.** These results are supported by a conservative statistical simulation that shows that the cost and benefits are likely to break even or be better.

A limitation to these findings is that the benefits reference class is only based on international projects and may therefore underestimate the risks to the Arctic Circle Road. However, this is taking the conservative assumption that Arctic roads carry higher risk than temperate roads (counter to the analyses that found no statistical difference). Further, the strongly reassuring results of the sensitivity analysis and conservative statistical simulation give confidence that the Arctic Circle Road can achieve a positive benefits-to-cost ratio.

The benefits deep dive finds strong alignment between the arguments made in the business case and the perspectives presented by stakeholders. While stakeholders' views are subjective and may be prone to bias, we find sufficient supporting evidence in the case studies to conclude that the primary tourism benefits presented in the business case are plausible. Other benefits including associated investment, lower cost of living, and enabling science and research are also supported. The business case may also have under-estimated the potential for wider socio-economic benefits.

In general, the assumptions that are required to hold for benefits to be realised all appeared to largely be in place. These include sufficient continued commercial operation of Kangerlussuaq Airport, road design and capacity, and supportive business and tourism environment. Given the link between transport infrastructure and population demographics, it is understandable why there are concerns that population decline in Kangerlussuaq may be precipitated by the potential decline in air traffic in Kangerlussuaq [52]. While it is possible this may reduce resident-derived benefits of the Arctic Circle Road, it is unlikely to undermine or negatively impact the benefits-to-cost ratio because the business case almost exclusively focuses on tourism-derived benefits. In addition, the Arctic Circle road itself can be thought to create population growth in the area. Therefore, the socio-economic benefits appraised in the business case are unlikely to be sensitive to changes in local resident demographics.

However, strategic dialogue is still required to establish and align the interests of key stakeholders, particularly private investors, the Government, and air traffic industry. Without this, there does not appear to be sufficient clarity and confidence to overcome uncertainties and begin committing to investment.

Conclusions:
The quantitative cost and schedule risk assessments of Arctic road projects show a need for budget and schedule uplifts on top of the base estimates depending on the risk appetite of decision makers.

While the cost estimates may be out of date and not reflect a single preferred route option, our cost sensitivity analysis shows that much higher construction costs can be tolerated for the project to still maintain a positive business case. However, it will still be necessary to obtain updated cost estimates after further investigations and surveys have been undertaken to identify construction challenges and opportunities along the preferred route.

Based on our statistical analysis, we find that the Arctic Circle Road is likely to achieve a positive benefit-to-cost ratio, even under a conservative scenario.

The analysis of the business case also indicates that the benefits are well-founded and are likely to satisfy a local need. Currently, the economic appraisal focusses narrowly on tourism benefits, so there might be scope for including further socio-economic benefits. Potential demographic change in Kangerlussuaq is unlikely to affect the benefits-to-cost ratio of the socio-economic analysis appraised due to the business case's almost exclusive focus on tourism derived benefits.

However, the project design and development require further work before a final decision. At present, the design of the road is very immature and needs to be developed to better understand uncertainties. Further investigations, design and preparatory works are required to determine and detail a single preferred option for the route and better understand construction challenges and opportunities. Once this is agreed, the cost estimates should be updated, and procurement processes could be initiated to scope out suppliers. If the updated estimates are considered affordable, an updated business case, including validation of potential investments and revenue benefits, would be expected to more precisely confirm the benefit-to-cost ratio. Further, decisions around regional investment strategies, cost sharing, and risk appetite are also required to advance the development towards a final decision.

Progression of the project and realisation of benefits is contingent on alignment of interests among the key stakeholders. Fostering synergies and reaching mutually reassuring and beneficial agreements that can provide confidence to progress to the next stage of decision making will require strategic dialogue.

At this immature stage of decision-making, it would be unusual for the government to require rigorous evidence of firm commitment for investment. Instead, we would expect to see clear signals of intent from both parties to progress with further investigations that would allow the project to progress to a more mature stage. It is the authors opinion that the business case provides sufficient favourable evidence to warrant investment in the further investigations required. Once further investigations are undertaken, this should provide the business community with the reassurance they require to invest in more robustly evidencing their commitment. Once this is done, a revenue analysis as part of an updated business case, including validation of potential investments and benefits, may be completed before a final decision is made.

In sum, our combined findings support a decision towards further advancement of the project, which at this stage would involve further investigations required to determine and detail a single preferred option for the route.

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1 INTRODUCTION

This report presents Oxford Global Project's (OGP) independent risk assessment of the Sisimiut–Kangerlussuaq Road Project (from now, the Arctic Circle Road).

The Arctic Circle Road is a proposed Arctic road connecting Sisimiut to Kangerlussuaq in Greenland. At 170km long and an expected budget of DKK 300-650 million, this road would be an ambitious undertaking. Both the Government of Greenland and Qeqqata Municipality are currently involved in the road planning, but the financial arrangements including cost sharing, have not yet been agreed.

While Arctic roads are common elsewhere, this road project represents a new frontier in road building in Greenland, being the first road between towns. Currently, all transport between communities relies upon passenger-approved boats, helicopters, planes, snow mobiles, or other self-transport across unimproved terrain.

The plans for the road exist within a wider context of upgrades and changes to transport infrastructure being considered in Greenland, particularly ports and airports. This dynamic situation raises the potential for unknown or difficult to foresee risk, complex interdependence, and differing viewpoints depending on the anticipated share of cost and benefits.

To support the difficult and significant decision making required by this complicated and potentially risky investment, The Government of Greenland have contracted Oxford Global Projects to carry out an objective risk assessment of the Arctic Circle Road business case, including reviewing the risks of cost and schedule overrun and benefit shortfall. This independent review will be important for helping the Government of Greenland to draw data driven and evidence-based judgements, upon which they can make unbiased and transparent conclusions.

Road name: **Arctic Circle Road**

Location: **From Sisimiut and Kangerlussuaq, Qeqqata Kommunia**

Length: **170km including existing roads. 153km new build**

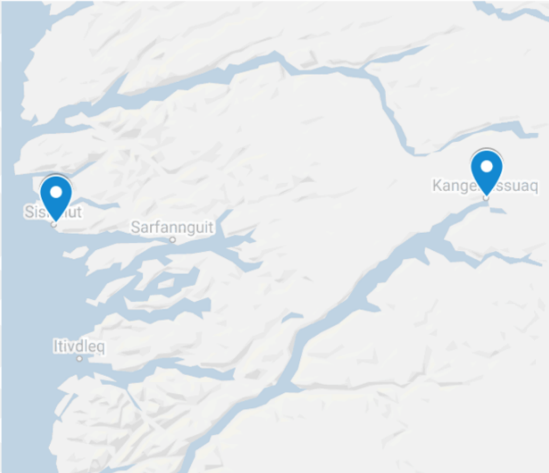
Planned build: **Two-lane road with a width of 2x3m and a 0.5m shoulder on both sides. Constructed using a thick bed of gravel**

Speed: **60km/hour**

Estimated traffic: **26-44 vehicles per day**

Estimated cost: **300-650M DKK (2019-prices)**

Estimated maintenance cost: **6.9M DKK per year**



Note: Traffic estimate for the full road based on numbers from the 2020 EIA report *VVM-godkendelse af vej fra Kangerlussuaq til Kangerluarsuk Tulleq*".

1.1 Background and Objectives

We understand that this risk assessment only represents the most recent juncture of what has been a long history of considering the Arctic Circle Road. It is also important to appreciate that this current scenario is not a stand-alone project, but one that is situated within the context of a proposed port expansion at Kangerlussuaq. These road and port plans are being considered to enable socio-economic development in the area including new tourism facilities and to make accessible the large ice-free area between Kangerlussuaq and Sisimiut.

We therefore wish to emphasise that this risk assessment focusses on reviewing the business case for the most recent Arctic Circle Road proposal. Further, while we are cognizant of the inter-related nature of Greenland's various infrastructure plans and possible associated private investment, the risk assessment deals mainly with the more immediate cost and benefit impacts of the road development, rather than speculate on all possible indirect effects. This more conservative approach is advised given the high level of uncertainty of indirect stakeholders' decision-making.

The objectives of this review were:

1. review the business case for the project,
2. provide an objective and independent review of the projects cost, schedule and benefits, and
3. make recommendations for the future of the project.

These objectives were delivered through three main workstreams:

1. **Business case review:**
    a. review of the business case to explore uncertainties
    b. testing for sensitivities to cost-benefit ratios
2. **Risk assessment:**
    a. a qualitative literature review of Arctic-specific road construction challenges, associated cost and schedule drivers, and risks of overrun and benefit shortfall,
    b. reference class forecasting to quantitatively assess project risks associated with cost overrun, schedule overrun, benefit shortfall
3. **Benefits deep dive:**
    a. primary research into the benefits case to test the supply-based assumptions from a stakeholder perspective,
    b. triangulation with case studies of realized benefits from other Arctic road developments.

The findings from these three workstreams are presented in the following sections.

It should be noted that it was originally intended that this report should cover reference class forecasting of operational costs. However, due to limited data availability, this was not possible. There was also limited data available on benefit shortfall for Arctic-specific road projects. Therefore, only a broad reference class based on normal road projects could be provided. To mitigate against under-estimation of risk and provide supporting information for decision-making, the literature review of Arctic-specific road construction challenges was provided.

2 METHODOLOGY

2.1 DATA FOR RISK ASSESSMENT

2.1.1 REFERENCE CLASS FORECASTING

To quantify the risks associated with the Arctic Circle Road project, we used a method called Reference Class Forecasting (RCF). RCF takes an "outside view" and can thus circumvent optimism. RCF predicts more accurate project budgets, schedules and benefits and allows to sense check the inside view forecasts.

Traditional forecasting techniques typically take an 'inside view'. They include a fixed contingency to the project cost estimate to account for risk and uncertainty in cost estimation, often 10% of the estimated cost. However, this method is considered to be biased because of the arbitrary way of deciding on the contingency amount.

The effectiveness of RCF depends on the similarity of the reference class. If the project fits well into the reference class, the resulting uplift from the RCF will provide a more reliable estimate of the cost of the project. Moreover, the effectiveness of RCF is in general influenced by the size of the projects and the size of the reference class; projects need to be sufficiently large and the reference class should include enough projects. If these criteria are met, RCF will outperform other estimating approaches.

Reference Class Forecasting makes explicit, empirically based adjustments to estimates. To be accurate, these adjustments should be based on data from past projects or similar projects elsewhere and adjusted for the unique characteristics of the project in hand.

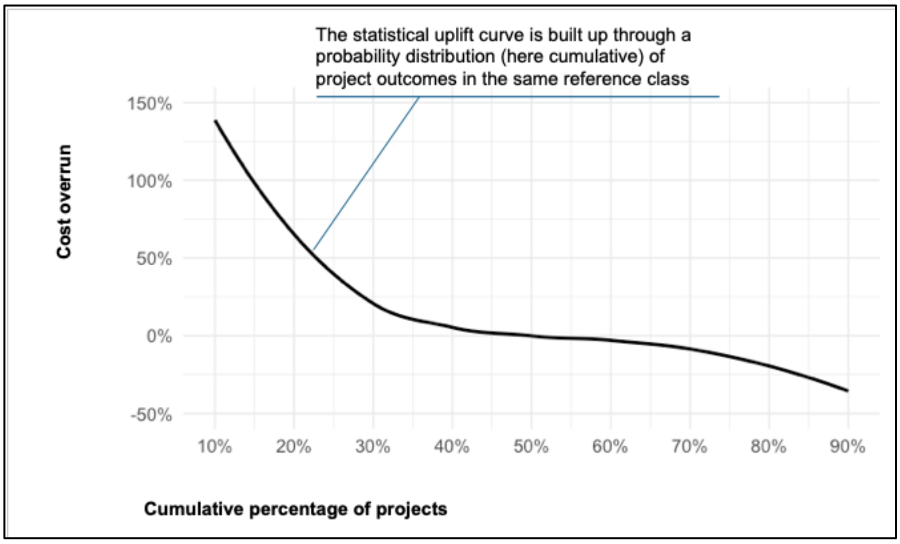
Reference Class Forecasting follows three steps:

1. Identify a sample of past, similar projects – typically a minimum of 15-30 projects is enough, but the more projects the better;
2. Establish the risk of the variable in question based on these projects – e.g. identify the cost overruns of these projects; and
3. Adjust the current estimate – through an uplift or by asking whether the project at hand is more or less risky than projects in the reference class, resulting in an adjusted uplift.

First, a reference class is selected. The key to a reasonable reference class is a broad selection of projects, so that all available information is included, and no potentially informative data are thrown out. In order to establish what is comparable information, statistical analysis is used to eliminate the risk of re-introducing optimism into the analysis by excluding valuable data.

Second, the distribution of the data in question is analyzed. For this, the cumulative distribution is constructed. In the case of overrun the data are simply sorted from largest to smallest overrun and then the relative share of each data point in the sample is calculated (e.g., if 25 projects are in a reference class each project has 4% share) and summed up so that the distribution ranges from 0%-100% (i.e., the project with the largest overrun project represents 4%, the second highest overrun 8% and so on. Figure 1 depicts how the cumulative distribution curve of these data are then charted.

Figure 1: Cumulative probability distribution of overrun in the reference class (conceptual)

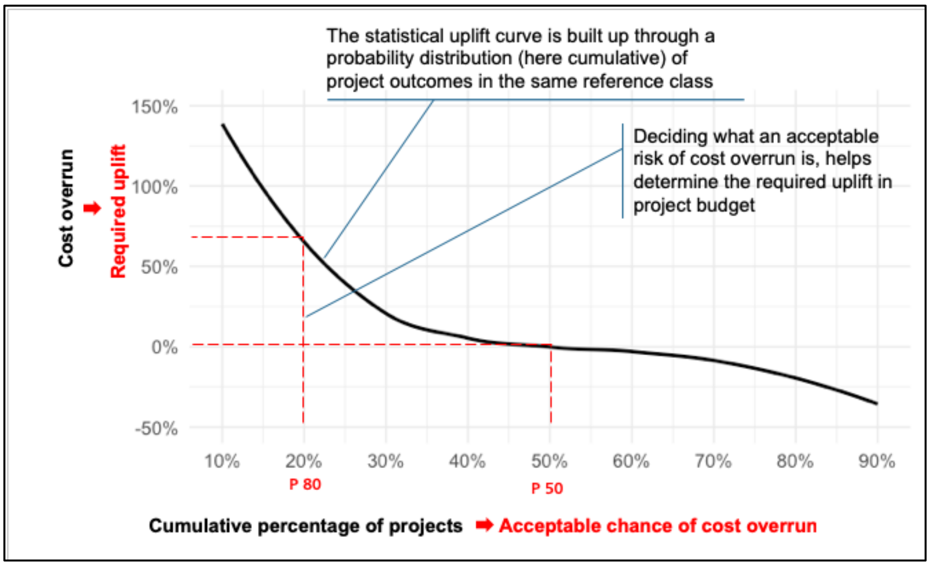


Third, the cumulative distribution is then used to identify the necessary uplifts to de-bias the estimates. For this, the curve (see Figure 2) is reinterpreted. The cumulative percentage of projects with a given overrun in the reference class now becomes the acceptable chance of overrun.

The overrun becomes the uplift necessary to de-bias the inside estimate. For example, if decision makers accept a 50% chance of overrun (i.e. they require a 50% certain estimate or P50) then a certain uplift should be added. If decision makers are more risk averse and only accept a 20% chance of overrun (i.e. they require a 80% certain estimate or P80) then a larger uplift needs to be added.

It should be noted that the distribution is based on the historical overruns in similar, completed projects. Thus, projects might need to consider whether any additional adjustments to the chosen level of certainty, P-level, are needed. In other words, whether the project at hand is more or less risky than past projects.

Figure 2: Establishing the uplifts as a function of the acceptable chance of cost overrun based on the cumulative distribution of cost overrun in the reference class (conceptual)



2.1.2 DATABASE

To quantify the risks on cost, schedule and benefits associated with the project, we drew data from OGP's database, which contains 1646 completed road schemes from all over the world. The database contains data on performance of cost (n=977), schedule (n=340) and benefit (n=793).

Constructure within Arctic regions is associated with Arctic-specific challenges and drivers of cost and schedule. These can further increase project risk if not accounted for and mean that a risk forecast based on projects carried out under normal conditions may underestimate risk. Therefore, a reference class of similar Arctic projects should be constructed, analyzed separately, and then compared to a similar class of projects carried out under normal conditions. In this way, we can test if Arctic roads are different from normal roads in terms of the distribution of cost and schedule overrun.

Accordingly, Oxford Global Project collected additional data on Arctic Roads. Data was collected through in-depth searches of public repositories of arctic infrastructure, including The Wilson Center's Arctic Infrastructure Inventory which contains nearly 8000 projects over $10m, many over $100m, and several falling into the class of "mega-projects" [4]. The definition of *arctic* was derived from the Arctic Council Working Group's AHDR, AMAP, and CAFF boundary inclusive of Alaska, northern Canada, Greenland, Iceland, Siberia, and the northern Nordic block.

More than 60 projects were examined for inclusion in this report with concentration on arctic roads. Ultimately data with high similarity to the Arctic Circle Road was available for N=16 cost and N=14 schedule data points. The projects originated from the geographical regions Alaska, Canada, Finland, Norway and Russia. Despite additional and wider searches, we were unable to identify further relevant projects. the paucity of data available is reflective of the limited information available on Arctic road projects, despite rapid growth in Arctic projects [1]. This situation is confirmed by the Wilson Center's Arctic infrastructure inventory, which despite years of research and had little complete information for the roads listed [4].

Figure 3: Boundaries of the Arctic Council Working Groups

2.1.3 Data preparation

Reference Class Forecasting requires a like-for-like comparison. For cost reference class forecasts, specifically, projects need to compare outturn cost with cost estimates at the same price level and comparing real-term estimates with real-term outturn cost. The price level of a cost figure is adjusted to the year of the estimate and to the currency of the estimate. Similarly, cost forecasts have been stripped off contingency.

To account for inflation, we used country-specific GDP implicit deflators from the World Bank[1] to adjust price levels of cost estimates to the same year for the projects in the data sample. The deflation data from World Bank was chosen to ensure comparability to international cost figures by using the same deflation index for all the projects in the data set. Deflation was done for the minority of the projects, since many of the OGP data are derived from research, in which case costs are commonly listed in real terms. The GDP implicit deflator is the ratio of GDP in current local currency to GDP in constant local currency.

For currency exchange rates, we used official exchange rates from the World Bank[2] to standardise cost estimates of the projects in the data sample. Official exchange rate refers to the exchange rate determined by national authorities or to the rate determined in the legally sanctioned exchange market. It is calculated as an annual average based on monthly averages (local currency units relative to the U.S. dollar).

Cost overrun is calculated as *Actual Cost / Estimated Cost – 1*, where estimated cost is measured at the relevant business case stage and actual cost at project completion. The estimated cost is the base cost, i.e., the estimated cost excluding provisions for risk or optimism bias.

[1] GDP implicit deflators are based on World Bank national accounts data and OECD National Accounts data files. Source: "GDP Deflator (Base Year Varies by Country)." *The World Bank Data*, World Bank, https://data.worldbank.org/indicator/NY.GDP.DEFL.ZS.

[2] Official exchange rates are based on data from the International Financial Statistics database under the International Monetary Fund (IMF). Source: "Official exchange rate (LCU per US$, period average)." *The World Bank Data*, World Bank, https://data.worldbank.org/indicator/PA.NUS.FCRF.

Schedule overrun is calculated as *Actual Schedule / Estimated Schedule – 1*, where estimated schedule is measured from the approval of the relevant business case, i.e., the date of decision to build to the planned date of completion. Actual schedule is measured as the time passed from the date of approval to project completion as the date of actual opening.

Benefit shortfall is generally calculated as *Actual benefits / Estimated benefits -1*. Except in the few cases where the estimated benefits are negative in which the benefit shortfall is calculated as *(Actual benefits – Estimated benefits) / Estimated benefits -1*. Benefit data is estimated for the first years of operation. If data is not available at first year, then the first reported year of operation within the first 5 years after opening is used as a proxy of the benefits achieved.

2.1.4 QA PROCEDURES

The Oxford Global Projects data used for the RCFs have undergone strict quality assurance procedures. The OGP team collects data, which is then reviewed by a separate person on the team. Statistical analysis including inspection of histograms, various hypothesis tests and outlier analysis is then used to identify any anomalies, which are inspected and corrected if necessary. In addition, most of the transport data in the OGP database have been used in academic research and have thus been peer reviewed.

2.1.5 Literature review of arctic-specific road construction challenges, associated cost and schedule drivers, and risks of overrun and benefit shortfall

Ideally, a breakdown of risk by major sub-categories, known as asset classes, is calculated in addition to the overall cost or schedule overrun. However, the ability to do this depends on the granularity of data available. Benefit shortfall is also important because alongside cost and schedule overrun, it is the most socio-political and economically salient aspect of a project. However, like other asset classes, benefit shortfall is not always possible to calculate because relevant data may not be available. This is a common problem because such detailed information is generally only present in internal documents.

As mentioned previously, we were unable to calculate Arctic-specific reference classes for benefit shortfall and operational costs due to unavailability of data. Detailed breakdown of cost and schedule data by asset class or activity type were also unavailable. This meant that while an overall reference class for cost and schedule were developed, the specific drivers of costs and schedule (for instance, how much drainage contributes to cost overrun) could not be disaggregated.

Where complete and detailed quantitative data are unavailable, it is common to complement higher-level quantitative findings with more detailed explanatory data from other relevant primary and secondary qualitative sources. This mixed-methods approach permits triangulation of findings that can strengthen conclusions by drawing on multiple data sources and allows for explanations and underlying causes of the high-level quantitative findings to be hypothesised. Even when detailed data are available, use of mixed methods is considered good practice for ensuring that findings are contextualised within real-life situations. Essentially, the RCF provides quantitative evidence of risk based on historical similar projects, and the qualitative data provides evidence on what is likely to have caused these risks to materialise. This information helps to formulate overall judgements and conclusions.

To this end, we conducted a qualitative review of the key Arctic-specific drivers associated with cost and schedule overrun and benefit shortfall, and conducted interviews with Arctic Circle Road stakeholders. The methodology for the interviews is presented in the following section.

Our literature search included academic literature, policy documents and whitepapers, professional publications and guidance documents, project briefs, technical reports, evaluations, and media reports. The full list of final documents included in the literature review is presented in the bibliography.

We used a metanarrative synthesis approach to analysing, consolidating, and presenting findings from the literature. This method was developed by scholars at University of London to provide evidence on a complex review topic commissioned by the UK Department of Health [2]. It is now considered the best practice method when synthesising evidence from a large and diverse body of literature with inconsistent study designs, no established norms for quality assurance, and when a broad understanding and appreciation for the topic is required.

It should be noted that when referring to literature with inconsistent study designs and quality assurance standards, this does not indicate the sources are unreliable. Rather, that they come from diverse fields with differing reporting requirements and study designs which cannot conform to standardised Cochrane-style demands for experimental designs and quantitative effect sizes that are required for results to be statistically combined in a systematic review. Thus, they often include academic or technical articles that are experienced-based or offer qualitative but robust explanations for a phenomenon.

Literature sources were read, and content of interest were extracted into a deductive (hypotheses driven) template with categories for the main areas of interest e.g. a cost driver. Content of interest is a term used in Content Analysis to delineate the textual content that is relevant to the research question. The data extraction template was then reviewed and the content from each category was summarised into a report section.

While this process will be inherently subjective, the independence of the researcher and years of expertise and training in this analytical method helps ensure a balanced and unbiased analysis. It should be noted that subjectivity should not be confused with the term "inside view" in RCF language. Inside view in RCF refers to only considering your own experience and data, and not looking outside to consider other relevant experience and learning opportunities. The process of conducting a literature review therefore represents an approach to taking an "outside view."

2.2 Data collection methods for benefit deep dive

In this section we present the data collection methods that were used in the benefits deep dive.

2.2.1 Principles of data collection

To comprehensively assess the possible benefits of the Arctic Circle Road it is important that evidence comes from more than one source, especially if the evidence is not objectively reliable. This is achieved through triangulation, where several data sources provide evidence on a particular issue and this evidence is compared to ensure the robustness of conclusions. Ideally, data should be collected using mixed methods. The concept of mixed-methods data collection for triangulation in contribution analysis is summarized in Figure 4.

In the benefits deep dive, data were collected in the form of documentary evidence, case studies, and interviews.

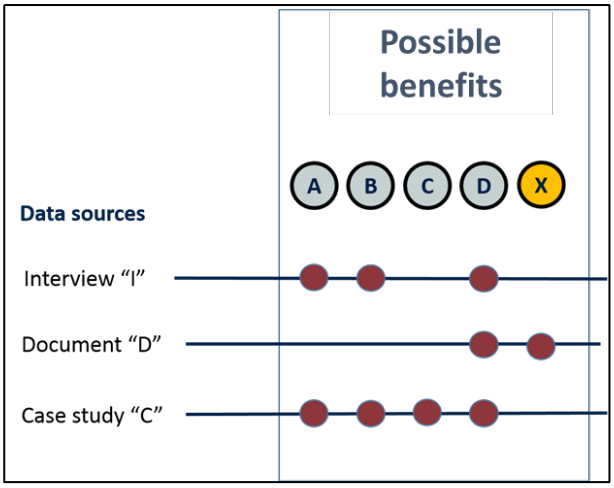
2.2.2 DOCUMENTARY EVIDENCE AND CASE STUDIES

Our secondary evidence consisted of official project documentation, including the business case, and reports provided by key stakeholders.

We also compiled case studies on similar road projects' benefits through the literature review mentioned previously. The literature referred to in this review is presented in the bibliography.

This information was used to supplement and test the plausibility of evidence provided by interview respondents. It was also used to help identify relevant stakeholders and characterise their influence and interest in the road project.

Figure 4: A conceptual representation of triangulation of data and sources



2.2.3 INTERVIEWS

Primary data collection is important for helping to answer and frame our assessment of benefits from a stakeholder perspective and will provide qualitative evidence where quantitative measures alone are insufficient. As mentioned previously, this mixed-methods approach is considered good practice for ensuring that findings are contextualised within real-life situations, which in this case in this inclusion of diverse stakeholder perspectives on the potential benefits of the Arctic Circle Road. This approach also allows us to examine the business case from demand perspective more deeply.

For the sake of clarity, it should be understood that respondents' contributions are not described or taken as fact by the researchers. The methodology employed in this study ensures that critical analysis is performed on potentially biased evidence, and no single source of evidence is considered sufficient. Instead, evidence from multiple sources are compared and contrasted to arrive at higher-level conclusions.

Key informant interviews were used to examine specific issues in depth, and where the nature of discussion could be sensitive. Interviews were semi-structured and followed a topic guide that contained prompts and sub-questions on key benefits of interest. The advantage of a semi-structured interview is that it maintains a focus on important questions that need to be covered, while still allowing for unanticipated but important information to emerge. Topic guides were tailored to explore the respondents' expert knowledge, and to triangulate and fill gaps in evidence.

In total 30 interviews were conducted during December 2020 and January 2021 (see Table 1).

Table 1: Summary of interviews

Interviewed stakeholder group	Number of interviews
Accommodation	3
Air Traffic	1
Environmentalists	2
Freight companies	1
Government of Greenland	4
Investors	4
Local businesses	6
Local residents	7
Municipality of Qeqqata	1
Science/research centres	4
Telecommunication	2
Tourist organisations	5

*In total 30 interviews were conducted. Some stakeholders belong to more than one stakeholder group, and thus the total amount of interviewed stakeholders pr. group totals 40.

Various stakeholders were suggested to OGP by the Working Group. Others were identified through the literature, document review and interviews. The Working Group consisted of representatives from the Government of Greenland, in particular the Ministry of Finance and Ministry of Housing and Infrastructure, as well as representatives from Qeqqata Kommunia and the business organization, Arctic Circle Business.

Stakeholders are defined as individuals or organizations that will be affected in some significant way by the outcome of the evaluation process or that are affected by the performance of the intervention, or both. While their contributions will always be subjective, the information and viewpoints that stakeholders provide are critical for understanding the potential benefits. This is because they will be active participants in the realisation of benefits or the recipients of benefits and their ascribed value. That is why inclusion of local stakeholders in infrastructure planning is now considered best practice.

Mapping and analysis of stakeholders is a critical exercise that helps to establish project stakeholder's interest, positions, alliances and knowledge related to the project, as well as the types of input they require, and what they expect from the project. This information helps to structure participants contributions, is important to consider when interpreting subjective contributions including any biases and helps determine how best stakeholders should be engaged with in the future.

2.2.4 Data analysis

Data were analyzed using a framework analysis approach [3]. This involves summarizing and condensing the most relevant information arising from a data collection activity and inserting the summaries into a framework matrix that links the evidence, and the source it came from, to each question in the framework matrix. Summaries can be tagged with information on where the contribution came from, including the expertise of the participant and any potential biases. The goal of this is not to exclude any particular view, and the tagging cannot be algorithmic, but rather to maintain a connection to where the data came from so that this can be considered when interpreting the evidence and drawing conclusions.

This evidence is then regularly reviewed to assess if it is robust enough to allow conclusions to be drawn from it. This process ensures that sufficient evidence from multiple sources regarding a particular issue of interest is collected and triangulated. The various sources of evidence can be easily compared and contrasted to identify convergent or divergent evidence and robustly draw conclusions from an otherwise complicated dataset. This process is known technically as “data saturation”, but essentially means to continue with data collection until no new themes in evidence are identified and all themes have supporting evidence from multiple sources.

In essence, the framework matrix is a two-by-two table that lists areas of interest in row headings and sources of data in column headings. In the case of our review, major row headings included: benefits, quantitative benefits, disbenefits, no build consequences, and assumptions for the road to be a success.

The summarized evidence is inserted into the cell where the source of evidence and issue of interest (to which the evidence relates) intersect. In a final column the evidence relating to the issue of interest is consolidated and conclusions are drawn. In the case of our review, this involved summarizing the evidence under the benefits headings by stakeholder group. Table 2 illustrates the framework matrix format and how it will be used to link evidence to the key benefit areas.

Data analysis was done as soon as data are collected. This means that conclusions begin to develop during data collection and become finalised soon after data collection is complete. This approach ensures that data collection is reflected upon while the information is still ‘fresh’, and allows for emergent issues and data gaps to be identified and followed up for investigation so that data saturation can be reached.

Table 2: Framework analysis matrix

	SECONDARY DATA			PRIMARY DATA			CONCLUSIONS
KEY BENEFITS AREA	Project documents	Stakeholder documents	Literature	Interview 1	Interview 2	Interview 3	Consolidated benefit findings by stakeholder group
Benefits							
1							
2							
3							
Disbenefits							
1							

2							
3							
No build							
1							
2							
3							
Assumptions							
1							
2							
3							

3 Risk assessment

3.1 Review of Arctic-specific road construction challenges, associated cost and schedule drivers, and risks of overrun and benefit shortfall

The following section presents our findings from the literature review on Arctic-specific road construction challenges, associated cost and schedule drivers, and risks of overrun and benefit shortfall.

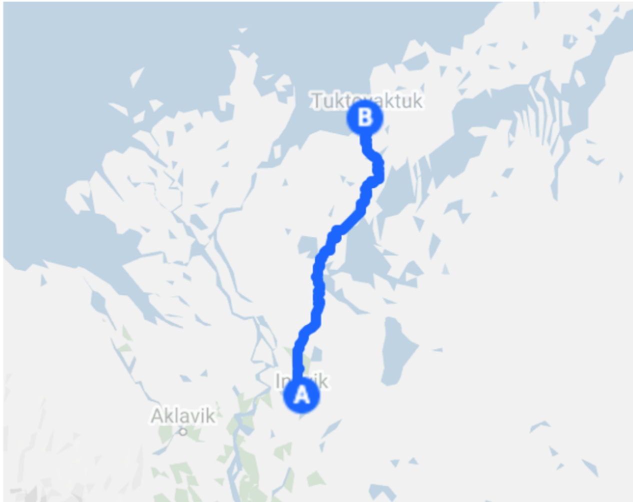
In line with the RCF approach, we draw on examples of Arctic road construction projects to help demonstrate historical experiences wherever possible. The most frequently referred to example in this report is the recently completed Inuvik to Tuktoyaktuk Highway. To help contextualise this example, summary characteristics of the Inuvik to Tuktoyaktuk Highway are presented in Figure 5.

It should be noted that the example of the Inuvik to Tuktoyaktuk Highway is presented most frequently because of the relative richness of information available, compared to other Arctic road projects. However, it should not necessarily be considered more applicable to the Artic Circle Road than other Artic roads included in the reference class forecast. Indeed, the Inuvik to Tuktoyaktuk Highway is about three times more expensive than the Arctic Circle Road estimates. While we were not able to identify an explicit reason for its higher cost, the additional cost will at least in part be driven by the requirement to build on particularly challenging shifting permafrost and its extreme remoteness at the end of the already remote 736 km Dempster Highway, which terminates at Inuvik.

The rationale for the Inuvik to Tuktoyaktuk Highway is also different to that of the Arctic Circle Road, in that benefitting tourism was not a key aspect of its business case, and it was not primarily intended to link with any major transport infrastructure at the time of decision to build (although it is hoped that it can service an anticipated deep-water port at Tuktoyaktuk). Rather the main social purpose was the extension of the Dempster Highway to grant improved access and socio-economic benefit for remote communities, and the economic rationale was founded on making exploration for oil and gas in the region more efficient and therefore attractive for oil and gas development (this was subsequently not possible due to a governmental drilling ban in the Arctic).

Figure 5: Summary details of the Inuvik to Tuktoyaktuk Highway

Road name: **Inuvik to Tuktoyaktuk Highway**	
Location: **Northern Canada. Inuvik, population 3000. Tuktoyakuk, pop. 800.**	
Length: **138 km**	
Build: **All season, 2-lane, highway constructed using a thick bed of gravel & geotextile fabric along the entire length**	
Date of decision: **Aug 2009**	Construction start date: **2014**
Estimated opening date: **Jun 2016**	Actual opening date: **Nov 2017**
Schedule overrun: **20.5%**	
Estimated cost (real cost): **CAD $257M (2019)**	Actual cost (real cost): **CAD $310M (2019)**
Cost overrun: **21%**	Maintenance costs: **CAD $12,000 – 15,000 per km (2019)**
Estimated traffic: **150 – 200 vehicles per day**	First year traffic: **41 vehicles per day**
Traffic shortfall: **73-80%**	



3.1.1 Underlying challenges to road construction in the Arctic

The following section provides a summary of the underlying challenges to Arctic road construction that drive costs and schedule and can cause overrun or benefit shortfall.

3.1.1.1 Geology

Arctic geology can be highly variable, ranging from solid basement rock, to gravel or silty sand, or peat. Solid basement rock usually offers favourable building material, but the quality can be patchy, especially over fault lines. Gravely sand offers good road construction material, but silty sand is prone to either being water saturated or dry depending on the season [4]. Peat can be very problematic causing many kinds of geotechnical issues that can give rise to problems with road performance [5].

3.1.1.2 Permafrost

Areas affected by permafrost present major challenges to road construction due to rapid increases in water from seasonal thaw and poor drainage caused by the impermeable frozen subsurface. Thawing of the active layer of permafrost below the road, combined with heavy rain or flowing meltwater, can lead to the erosion and the washing away of road materials and potentially road collapse [6]. Site construction will also be hampered due to wet and muddy conditions created by the melting ice and snow [7]. Prevention of these issues is largely reliant on ensuring adequate drainage to allow for water to drain away.

The Southern area of the planned road from Sisimiut to Kangerlussuaq lies in a discontinuous permafrost zone, while the northern area has continuous permafrost. These areas are also subject to spring melt and heavy precipitation that can result in high runoff-precipitation intensity. However, investigations in Southern Greenland identify that road drainage is a problem [4].

3.1.1.3 Climate change

Climate change is exacerbating challenges related to permafrost and the thawing of frozen water. Increases in temperature and warmer wetter summers are resulting in more frequent freeze-thaw cycles [5] and widespread degradation of the near-surface permafrost [8]. Among the many adverse effects this has, thawing permafrost causes ground instability that can severely damage Arctic infrastructure [9].

In Alaska, $1.6-2.1 billion USD of cumulative damages are due to thawing of permafrost from 2015-2019 [10], and The U.S. Arctic Research Commission (ARC) estimates that over 450 miles of highway will be susceptible to structural instability as the permafrost melts [11]. It is therefore important that all new road developments carefully take into consideration the influence of climate change and its increasing impact on project risk and future operational costs. Greenland is no exception given its rapidly melting permafrost [12].

3.1.1.4 Environmental protection and conservation

Arctic ecosystems are extremely sensitive to pollution and environmental degradation. Polluting materials break down slowly in the Arctic environment and therefore accumulate over time. Surface water is particularly sensitive to contamination in Arctic regions because thawing and heavy rainfall transport pollutants to lakes [4]. The extreme nature of the climate means that plants and animals in the area are usually living on the edge of the maximum carrying capacity of their habitat. Therefore, a small effect from construction operations may have a large impact [13]. Arctic regions are also typically rich in sites of archaeological or anthropological significance. Road construction has the potential to damage these sites and so care must be taken to minimize this [4].

Recent years have seen increased attention paid to preserving Arctic ecosystems and demand for developers to act with greater responsibility, as stipulated in the Arctic Investment Protocol [14]. Infrastructure development is now subject to strict environmental legislation and damaging or destroying nature within environmental areas are criminal offences [15]. While good for the environment, these new measures can lead to increased costs, schedule delays, and unexpected risks materializing. The Sisimiut–Kangerlussuaq road project will have to pay close attention to these risks given that the route passes a UNESCO World Heritage Site, Sisimiut´s drinking water reservoir, many important prehistoric remains, and 12 locations that are covered by the Conservation of Nature law [4].

3.1.1.5 Extreme working conditions

Extreme weather, isolation from settlements and services, and difficult working conditions all make construction including labor efficiency, use of equipment, transportation, and infrastructure, more difficult [13]. Remote locations also mean that sites do not have access to the usual services, supply lines, amenities, and other resources that are required for normal construction. This makes Arctic road construction slower and more costly, prone to project management risks, and increases health and safety hazards [16].

3.1.2 Arctic-specific cost and schedule drivers and risks of overrun

Arctic-specific challenges to construction result in construction projects costing 2-5 times more than similar projects in temperate regions (note that this refers to overall cost and not cost-overrun). They are also more prone to delays [17]. The following section presents the Arctic-specific drivers of cost and schedule when building roads and considers the associated risk of overrun.

3.1.2.1 Complying with environmental regulations and good practices

Complying with environmental regulations and good practices comes with significantly increased costs and schedule associated with detailed environmental surveys, and preventative or mitigating measures. The most severe risks are associated with failing to meet environmental standards. In non-arctic regions, a typical mitigation measure during construction is to provide alternative habitats by replacing or reinstating areas that were damaged in the past. In the Arctic this is not possible. Instead, an extensive and long-term baseline survey of the local habitat is necessary to document pre-existing conditions and help establish what must be done during the operational and reclamation phases [13]. These surveys can be very expensive, especially where more rigorous studies are required to give evidence on controversial issues [18].

Pollution and poorly planned waste management can give rise to high clean-up costs. If there are concerns about possible contaminations, a systematic sampling and testing program will be required [15]. Contractors also have a legal responsibility for any damage that may occur, and breaches in environmental law can lead to extremely high legal and remediation costs. During the construction of the Inuvik Tuktoyaktuk Highway, waste had to be trucked out, dust suppressant was applied, and technologies to minimize noise were used. A wildlife protection plan was also put in place, including worker education, protection of water resources, and the recruitment of wildlife monitors [19].

In terms of schedule, the main risk is needing to adjust the planned route to avoid sensitive sites, for example habitats of endangered animals, or important archaeological sites. While these may have been identified through planning surveys, it is likely that some will have been missed and only become apparent during construction [4]. Short or long delays may also be caused by wild animals coming near construction works. For instance, when building the Inuvik Tuktoyaktuk Highway, construction had to cease if an animal came with 500m of operations, and works were paused during caribou migration season [19].

3.1.2.2 Community consultation and environmental impact assessment

Community consultations and environmental impact assessments are important elements of the planning process. They safeguard the interests of stakeholder groups that may be impacted by the road development and ensure that environmental damage is minimized [14]. However, the approval process for a project to go ahead can be lengthy, not only due to the necessary surveys, but also the level of engagement required.

In preparation for the Inuvik Tuktoyaktuk Highway, formal community engagement activities took three years (from 2010-2013), despite many previous discussions [19]. The Ambler road project in Alaska (a 338km Arctic highway from the Brooks Range to the Ambler mining district) has faced particularly heavy opposition [11] which has resulted in an extended consultation period. Although an environmental impact statement is expected in 2020, future court battles are expected to further delay construction [18].

3.1.2.3 Extreme working conditions

Arctic weather conditions are always challenging. But due to the need to preserve permafrost, it is common for road construction to take place only in the winter months [20]. Under such extreme conditions, work slows, and the chance of delays is increased. A major impact of cold conditions is the effect it has on the workforce. Manual labor efficiency drops to 73 percentages of optimal workforce efficiency at minus 20 degrees, and between 53 and 35 percentages at minus 30 degrees [17]. Sub-zero temperatures also cause additional wear and tear on construction equipment resulting in breakdowns that can cause delays. These become magnified by lack of nearby repair services or parts [21]. Temporary construction disruptions due to bad weather causes short delays but being cut off from supply lines can prevent work continuing.

Given, the limited work windows dictated by the requirement to work only in winter or summer, such unexpected delays can have serious knock-on effects for schedule overrun. Long or continuous shifts may be needed to meet schedule requirements or minimize the risk of delay. When building the Inuvik Tuktoyaktuk Highway Construction crews faced temperatures of -30 to -50 degrees with wind chill, high winds, and 24-hour darkness. Warming shacks had to be provided and crews working in -20C weather had to take warming breaks every 40 minutes [22].

Ultimately, Arctic conditions greatly amplify schedule risk to the point that small surprises can cause unusually long delays, and major surprises may delay work for a whole season. To avoid such situations, careful planning and engineering redundancy are required. However, such contingencies and requirement for regular work phases results in increased equipment and labor costs [23].

3.1.2.4 Drainage

Poor drainage is a major problem in Ireland, Scotland, Norway, Sweden and Finland, with only Iceland having adequate road drainage [5]. When mistakes are made, they can be extremely costly. For example, elevated moisture and warmth due to incorrect embankment heights have melted permafrost and caused road collapse along the Dempster Highway. While the highway is drivable, maintenance costs have more than tripled over a decade, to $5.1 million in 2016 [8].

Improving drainage can increase road lifetime by a factor of 2.6 to 5 depending on the study [24]. Good drainage is also essential for preventing construction delays due to waterlogged building site conditions. However, the initial construction costs can be significant and should be accompanied by investment in a drainage management system to ensure drainage is monitored and kept in good condition [5]. For example, the Inuvik-Tuktoyaktuk Highway in Northern Canada had to use a “fill only" design (as opposed to "cut and fill") to prevent permafrost melt, laid geotextile fabric along the entire length of the 138km highway and invested in regular drainage surveys [19].

3.1.2.5 Transportation costs

Projects located in the Arctic may be hundreds of kilometers from any road, port, or population. The intervening terrain may have no permanent human presence, and existing transport infrastructure will be poor quality, seasonal (e.g., ice roads) or weather dependent, and thus slow and unreliable. When no existing transport links are available, all material, equipment and labor must be transported over purpose-built infrastructure [13], including the road that is under construction [4]. This significantly adds to routine labor and material costs.

3.1.2.6 Labor costs

Training, labor, and maintenance of the workforce are particular cost drivers of artic road construction, and in some circumstances can be prohibitively expensive. Suitably qualified personnel are rarely available, so road projects must recruit and train local people with the requisite skills [13]. In the absence of local settlements and transport links, the workforce will need to be stationed at the construction site for extended periods. They will need to be provided with accommodation, food, healthcare, and social and recreational amenities [17]. These resources need to be rapidly deployed to offer protection while the construction site is being set up and must function "off grid" in terms of power and water services. These indirect labor costs can be very significant [21].

The relative size of the required workforce, and therefore direct and indirect labor costs, will also be larger when compared with similar projects in temperate regions. This is due to the decreased labor efficiency in Arctic conditions, and the need for continuous work shifts to meet limited seasonal schedules. When building the Inuvik Tuktoyaktuk Highway contractors had to provide training courses to respond to the need for capable truck and heavy equipment drivers. Due to the time and expense of getting workers to the site (60km from closest city), most lived in construction camps. For the sake of efficiency, staff worked in shifts around the clock [20].

3.1.2.7 Material costs

Arctic roads usually only serve low volumes of traffic. This means they have to use relatively cheap materials to be a cost-effective investment. As a result, gravel is the most frequently used material [4]. Even when using gravel, material costs can be prohibitively expensive due to the massive quantities required. When unsuitable foundation material is identified, this may need to be removed and replaced with filling material, further increasing the volume of gravel needed [4]. Requirement for low capillarity grains (to reduce frost-heave and freeze thaw damage) and layering with geotextile fabric also increases costs [17]. The gravel used for the Inuvik-Tuktoyaktuk Highway is 2 meters deep in some places and the whole length of the highway is layered with geotextile fabric. Despite the CAD $299m investment, cost cutting measures had to be put in place to keep the highway on budget. This involved using less gravel on a 56km stretch of the highway (41% of the total length) and reducing the height of embankments [25].

A key determinant of the cost of gravel and suitable filling material is the availability in the area the road is being built. As mentioned previously, transportation is very expensive in the Arctic. Therefore, if local gravel and filling material deposits are available this can considerably reduce material and transportation costs [4]. In some cases, if suitable materials cannot be found near the planned route, construction is not possible [16]. The identification of these deposits through surveys is therefore essential for reliable cost estimates, and any mistakes that misidentify materials as suitable can result in large cost-overruns and schedule delays while alternative sources are found.

3.1.2.8 Site investigations and surveys

In the arctic, where risks are amplified, site investigations and surveys are a critical tool for reducing risk. They are required for determining route possibilities, understanding the quality of foundational material, identifying suitable construction material deposits, understanding drainage patterns, environmental impact assessments, and pollution control and monitoring [17].

The cost of survey, analysis and selection may constitute 2-4% of the overall funding of a project, depending on the size, complexity, or controversy of the works [24]. However, survey costs can become extremely expensive [16]. The Alaskan state government has spent more than $26m on advance studies in support of its proposed Ambler project and another $50m more is expected to be required to get to the construction stage. Estimates may minimize investment in surveying to reduce cost and timelines. However, this approach carries high risk given the construction and maintenance problems that can be caused by failing to identify problems [4].

3.1.2.9 Road maintenance

While not part of construction costs, road maintenance represents a major cost driver of Artic roads when considering whole life costs. Maintenance of the Inuvik-Tuktoyaktuk Highway is expected to be in the region of CAD $12,000 to CAD $15,000 per kilometer, which adds up to about CAD $1.5 million to CAD $1.9 million per year [26]. Such costs are only likely to increase given climate-related permafrost thawing. A conservative scenario of road infrastructure in 2020–2050 for nine Russian Arctic regions shows that the capital costs to maintain public roads located in permafrost regions will average at least $190m ($5,356.39/km) and will exceed $380m under the modernization scenarios. The conservative scenario assumes that the existing 35,471.64km of road infrastructure on permafrost will need constant additional capital investment to repair and maintain sustainable functioning due to permafrost degradation and the reduction of soil bearing capacity, as well as surface deformation due to thaw subsidence of ice rich soils. The modernization scenario assumed the reconstruction of 28344.53 km of existing roads, as well as the additional construction of 6837.29 km of new roads and 171 engineering facilities [27].

Poor quality [4] or insufficient building material [25] and drainage can dramatically increase maintenance costs. In Greenland, problems caused by poor use of gravel grain sizes and insufficient drainage cost about half a million kroner a year in maintenance[3]. Strengthening road surfaces after they are damaged also carries significant risk because major mistakes can be made when inappropriate strengthening structures are used [4].

3.1.3 Common benefit shortfalls in Arctic road projects

The following section presents a summary of the most frequently reported risks associated with benefit shortfalls in Arctic road projects.

3.1.3.1 Unrealized socio-economic benefits

Arctic road building is frequently associated with socio-economic benefits. The Sisimiut–Kangerlussuaq Road Project is expected to contribute millions of kroner to the local economy each year through increased exports, lower costs of living, and tourism [28]. However, such benefits are prone to shortfall if they are not carefully estimated or aligned with investment upon which the benefit depends. Road development can also bring socioeconomic drawbacks.

For instance, while the Inuvik-Tuktoyaktuk Highway succeeded in delivering many of its estimated socio-economic benefits, weight restrictions, road closures and other design flaws reduced the realized benefits compared to estimates [26]. There is also concern that the road may increase the availability and consumption of alcohol and drugs [29]. Further, the design and construction of the

[3] Please note that this cost is related to maintenance problems caused by poor use of gravel and insufficient drainage. Not total maintenance costs.

road did not consider the full scope of its use for the wider region and its economic activities; the utility of the road as infrastructure to service an anticipated deep-water port in Tuktoyaktuk are likely to be limited by road and weight restrictions [16], and the potential for supporting oil extraction has been prevented by a subsequent 5-year ban on drilling [30].

3.1.3.2 Restricted road use

Seasonal road closures, weight restrictions, or winter load premiums are often used to reduce road damage and associated maintenance costs, particularly during the Spring thaw. This increases the road lifetime but also incurs major additional costs for industries and communities. Therefore, the timing of the restrictions must be carefully determined to achieve maximum benefit [31].

The Arctic Circle Road is intended to be open all-year. However, it is worth noting that other arctic roads have experienced unexpected road restrictions due to design issues that meant the road must be temporarily closed until adverse conditions or damages are resolved. For instance, the extra costs to the forest industry due to spring thaw-weakening in Finland has been calculated to be 100M€, of which 65 M€ comes from public roads [4]. The newly opened Inuvik-Tuktoyaktuk Highway has faced unexpected road closures that have been a significant impediment to heavy transport vehicles [32].

3.1.3.3 Environmental trade-offs

Construction and operation of the Sisimiut to Kangerlussuaq road carries environmental risk in terms of pollution, damage to wildlife habitats, disturbance of flora and fauna, and changes to the landscape that may decrease its natural value. Pollution of Sisimiut's drinking water reservoir is a particular concern and increases in dust due to construction and traffic could directly impact on human settlements [4]. If such risks are realized, they could not only damage the environment and result in high clean-up or legal costs but also reduce the benefits upon which the business case is premised e.g., socio-economic gain from nature tourism and outdoor activities, and general quality of life and services.

To avoid a benefit shortfall, these environmental risks from road construction need to be understood in terms of their trade off with anticipated benefits. In the case of the Inuvik Tuktoyaktuk Highway, the main environmental impacts have included habitat degradation, disturbance and animal mortality. Dust generated by construction and road traffic is also a recognized problem, causing both environmental damage and unpleasant conditions for humans in the vicinity [29].

3.2 Quantitative Cost risk analysis

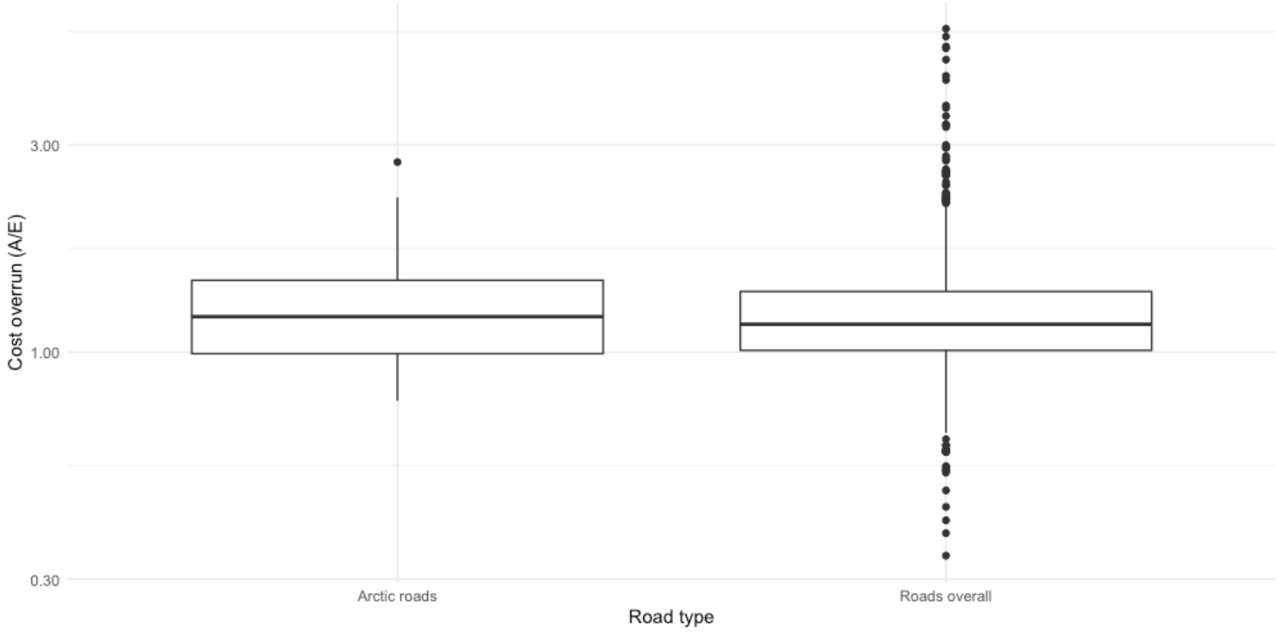
To quantify the cost risks associated with the project, we drew data from OGP's database, which contains 1646 completed road schemes. In addition, we examined more than 60 additional Arctic projects to analyze the particular performance of Arctic road projects. Ultimately, we considered the data quality to be satisfactory for 22 projects, of which data on cost performance was available for 16 projects. Since the effectiveness of reference class forecasting is often influenced by the size of the projects in the reference class, we accounted for the size of the projects in our samples in several different ways to ensure reliable forecasts. For this, we operationalized project size as (1) scheme length in kilometers, (2) estimated cost, (3) estimated length of delivery, after which we tested whether these variables influenced project cost overrun using regression analysis. For all the tests, we found no statistically significant correlation between project size and cost overrun.

In order to be accurate, reference class forecasting should be based on data from past projects or similar projects elsewhere and adjusted for the unique characteristics of the project in hand. For the Arctic Circle Road, we created two different RCFs to reflect the project's unique characteristics: (1) an arctic road RCF based on data other arctic road projects; (2) a tailored RCF utilizing a breakdown of the project at the asset class level.

3.2.1 Arctic road cost RCF

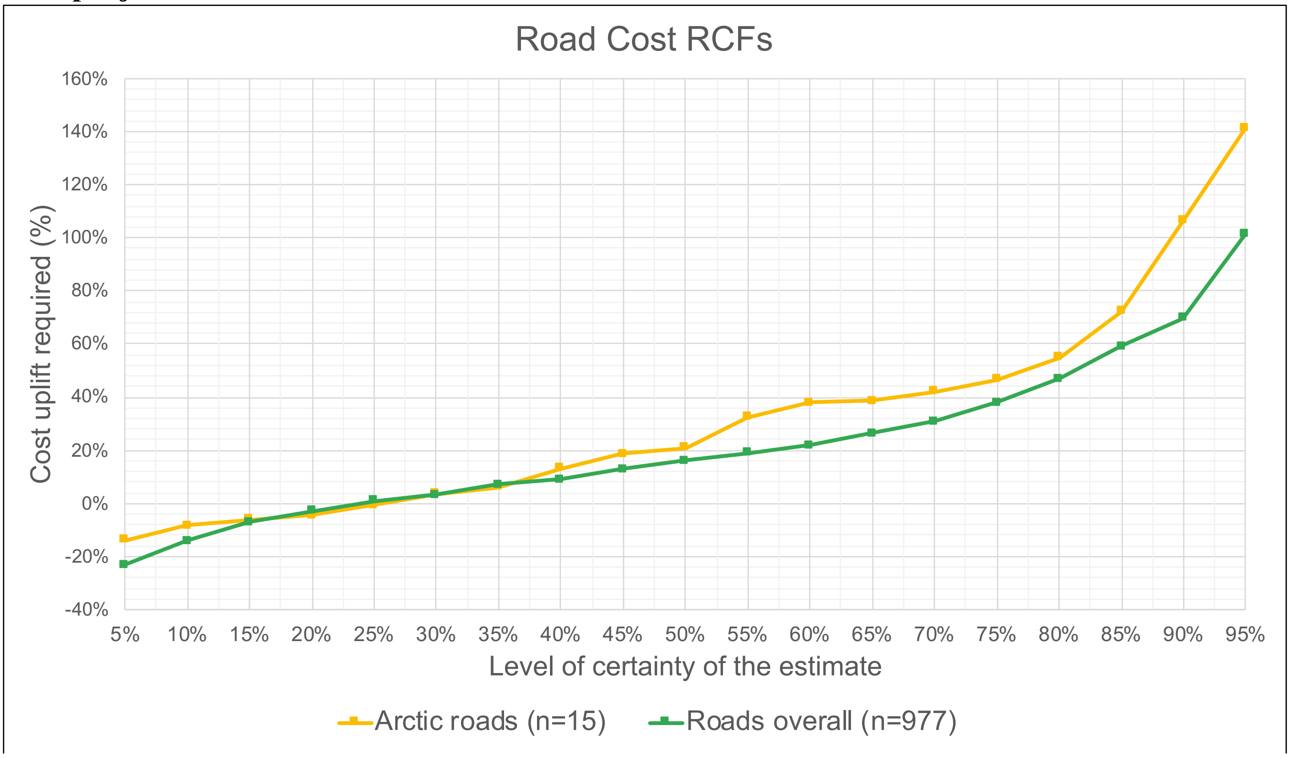
For the arctic roads RCF, we conducted statistical analyses of the sample of arctic road projects, comparing them to road construction projects worldwide to identify whether arctic road construction projects differ in terms of cost performance – i.e. budget deviation. Here, we found that the cost risk of arctic road projects was not statistically significantly different from the cost risk of road projects elsewhere ($p = 0.16$). The p-value testifies to the strength of the evidence; the test is significant if $p < 0.05$. Note that the p-values cited here are based on non-parametric Wilcoxon rank-sum tests, which are preferred when data do not follow normal distributions. Box plots displaying the data distributions of cost overruns for the arctic and worldwide road constructions are shown in Figure 6 below. The boxes show the middle portion of the data: the inter-quartile range (IQR). The bottom and top of the boxes mark the first quartile (the 25% mark – or P25) and the third quartile (the 75% mark – or P75). The thick bars in the middle of the boxes are the medians (P50). The upper whisker extends from the top of the box to the largest value no further than 1.5 * IQR from the top. The lower whisker extends from the bottom of the box to the smallest value at most 1.5 * IQR of the bottom. Data beyond the end of the whiskers are called "outlying" points and are plotted individually.

Figure 6: Box plots displaying distribution of cost overruns for arctic roads projects and roads projects overall. A cost overrun of 1 means that the project finished exactly on budget.



While this test indicates that the cost risk of arctic road construction is similar to that of normal road construction, the sample size of arctic road projects used for this test is rather small, which could lead to the non-significant result. In addition, the literature review emphasised that arctic road construction carries additional risks compared to road construction under normal conditions, which is an argument in itself for using an arctic road specific sample for reference class forecasting. Because of this, we use both the arctic road and worldwide road samples for the RCF analysis, with the worldwide sample being comprising the lower-bound risk position and the arctic sample comprising the upper-bound risk position for the Arctic Circle Road. Figure 4 below shows the probability distributions of cost overruns for both road samples. The data show that half the arctic road projects had a cost overrun of equal to or less than approx. 21%, while half of roads overall had a cost overrun of equal to or less than 16%.

Figure 7: Probability distributions of cost overruns for historical arctic roads and worldwide road projects



The data shown above are then used to establish the required contingency uplift as a function of the acceptable chance of cost overrun, i.e. the risk appetite of decision makers. In relation to the above figure, this is simply done by using the cumulative percentage of projects (x-axis) as the acceptable level of certainty that the project will finish on or below budget and the cost overrun (y-axis) as the required uplift to reach that level of certainty. For instance, if decision makers on the Arctic Circle Road project want a 50% chance of finishing the project at or below budget (P50), the project budget needs an uplift to the project base cost estimate by 16 to 21% based on the above distributions of overall road (lower-bound) and arctic road (upper-bound) cost overruns. On the other hand, if decision makers require a 70% (P70) certainty that the project will finish within budget, the base estimate would require an uplift of 31 to 42%.

3.2.2 ARCTIC CIRCLE ROAD TAILORED COST RCF

For the tailored cost RCF, we created individual reference classes for each asset class component of project. The strength of this approach is that it allows for further tailoring to the specifics of the Artic Circle Road project. For this analysis, we used the breakdown of the price estimate that Rambøll created for the road in 2004 and mapped the different cost components against data from the OGP database. An overview of the data that went into the blended RCF is shown in table 3 below.

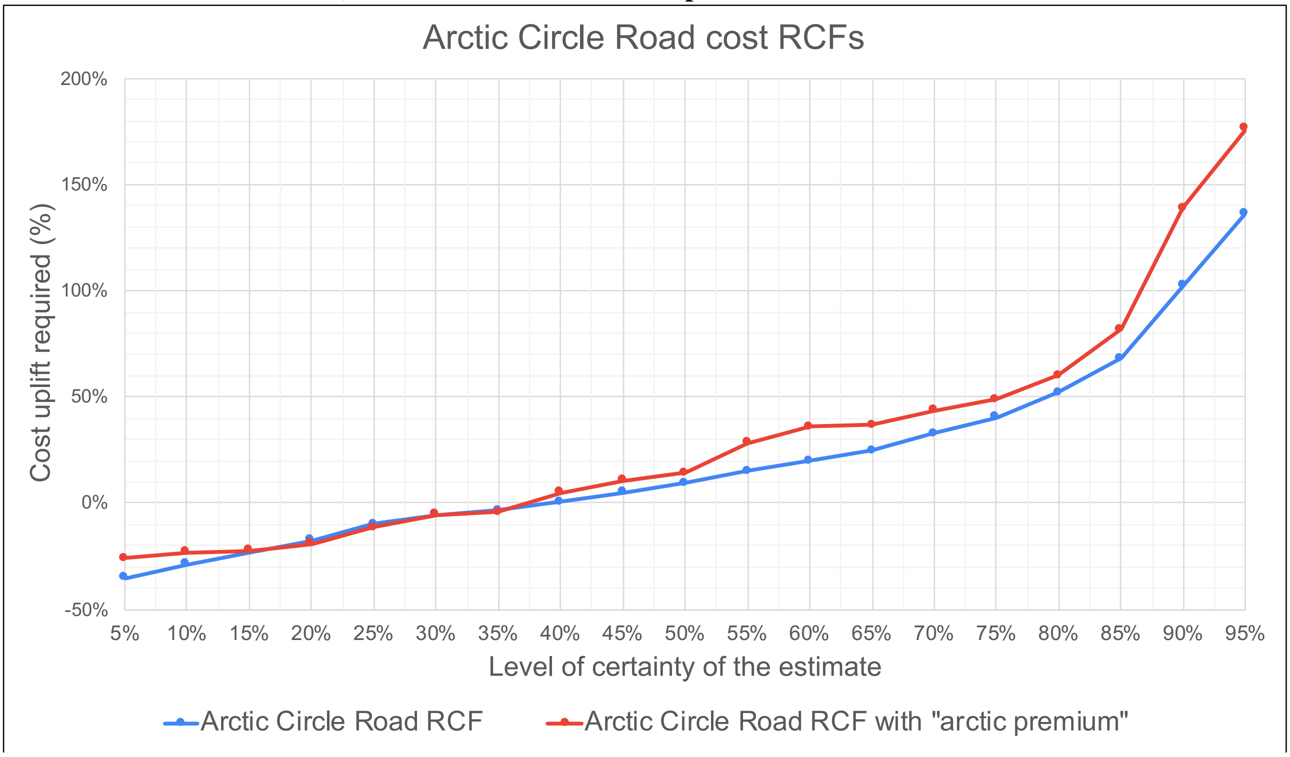
Table 3: Overview of data used for tailored Arctic circle road RCF

Cost heading	*Sample size*	*Indicative percentage of total cost estimate*
Preliminary works	35	**11%**
Earthworks	362	**18%**
Drainage	24	**32%**
Road surface works	977	**20%**
Blasting	71	**13%**
Construction supervision	44	**6%**

This analysis is based on the assumption that the Arctic Circle Road is neither less risky nor riskier than similar projects in other areas of the world. However as discussed earlier, there is a good reason to believe that there is difference in cost risk profiles between arctic and non-arctic roads, which is unaccounted for when relying on data from international projects. Thus, an RCF based on data shown in the above table might underestimate the cost risk found in the Arctic Circle Road.

Therefore, we add in what can be referred to as an *arctic premium* – the cost risk discrepancy between arctic and non-arctic road projects, e.g. the additional cost risk involved in building a road in arctic conditions versus normal conditions. Thus, we recommend accounting for the arctic premium by adding an additional static cost uplift to the project. The premium is quantified based on the gap between the cost risk found in worldwide road projects and the cost risk found in artic road projects at various P-levels. Once again, the two curves should be seen as lower and upper bounds for the cost risk estimate. The tailored Arctic Circle Road probability distribution (with and without the arctic premium) can be found in Figure 8 below.

Figure 8: Probability distribution of cost uplifts required for the Arctic Circle Road based on Rambøll cost breakdown, with and without arctic premium.



Once again, the data shown above are used to establish the required contingency uplift as a function of the acceptable chance of cost overrun. Using the tailored RCFs, decision makers requiring a 50% chance of finishing the project at or below budget (P50), the project budget needs an uplift to the project base cost estimate by 9 to 14% based on the above distributions of cost uplifts required without (lower-bound) and with (upper-bound) arctic premiums added. On the other hand, if decision makers require a 70% certainty that the project will finish within budget, the base estimate would require an uplift of 33 to 44% based on the tailored RCF data, which is very similar to the simple arctic and worldwide road RCFs at a 70% level of certainty of 31 to 42%.

3.2.3 Current cost estimates

Currently, three cost estimates for the Arctic Circle Road construction are available. To put the estimates into perspective, we have calculated the estimated costs per km, which is based on an projected length of 156 km in accordance with the 2004 bids from Rambøll and Mitterfeqarfiit, although option selection for the final route plan has not yet been finalized. An overview of the three cost estimates can be found in table 4 below.

Table 4: Overview of cost estimates for arctic circle road project, million DKK (2019-prices)

Estimate made by	*Total est. cost*	*Est. cost per km*
Rambøll (2004)	321*	2.1*
Mitterfeqarfiit (2004)	656	4.2
Socio-economic analysis	500	3.2

*The Rambøll cost estimate had 15% risk contingency removed from it. It is unknown whether the two other estimates include any contingency for risk.

While the above table is stripped off contingency, the Rambøll cost estimate originally had 15% additional cost added to it to address unforeseen expenses. To put this amount of contingency into perspective, 15% contingency equals a 50-55% chance of completing construction within budget (45-50% chance of cost overrun) based on the Arctic Circle Road tailored RCF data.

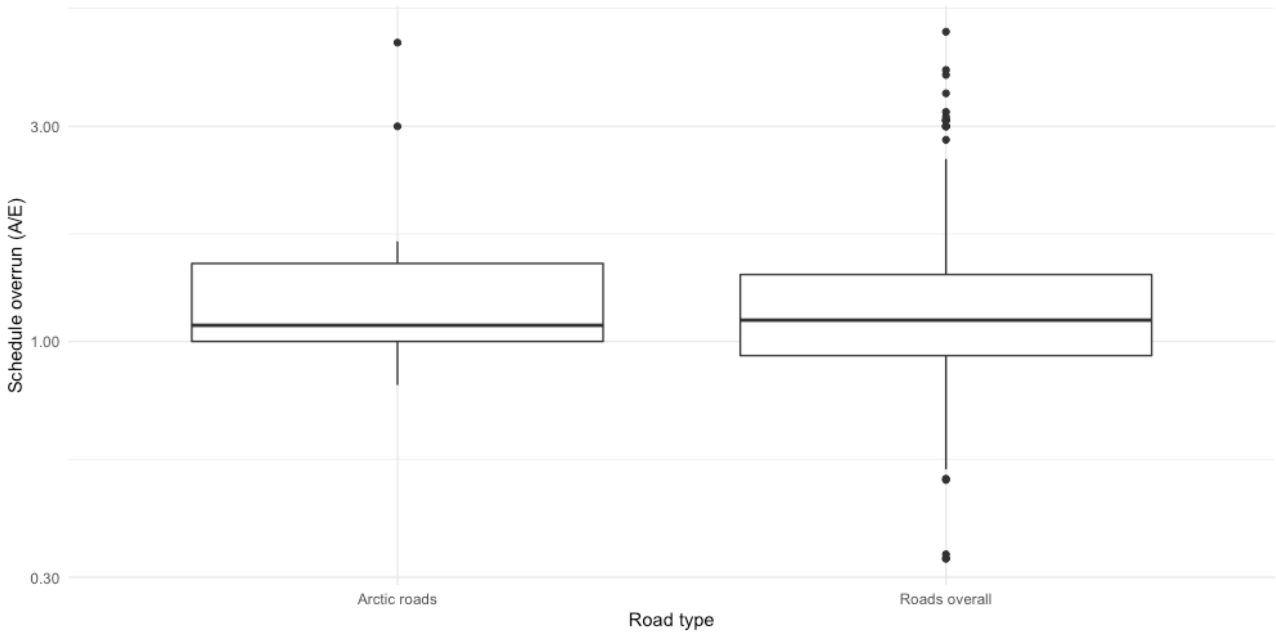
In addition, we have tested the sensitivity of cost construction cost figures found in the socio-economic analysis. Here, we identified how much the road construction cost for each of the two listed scenarios could increase while the cost-benefit calculation remained positive. The benefits-to-cost ratio remained positive with 241% increased road construction costs for Scenario A and 843% increased road construction costs for scenario B. Thus, the benefits case is robust in that it can sustain a large cost overrun while still being profitable.

Finally, it should be noted that the Arctic Circle Road cost estimates are now 17 years old. Therefore, we recommend updating the cost estimates after further investigations have been completed to identify and account for constructions challenges and opportunities, as well as to reflect current market rates. However, although potential build challenges and updated labour and material costs may increase the estimate, our cost sensitivity analysis suggests that the business case can tolerate more than tripling the road construction costs while still maintaining net positive benefits.

3.3 QUANTITATIVE SCHEDULE RISK ANALYSIS

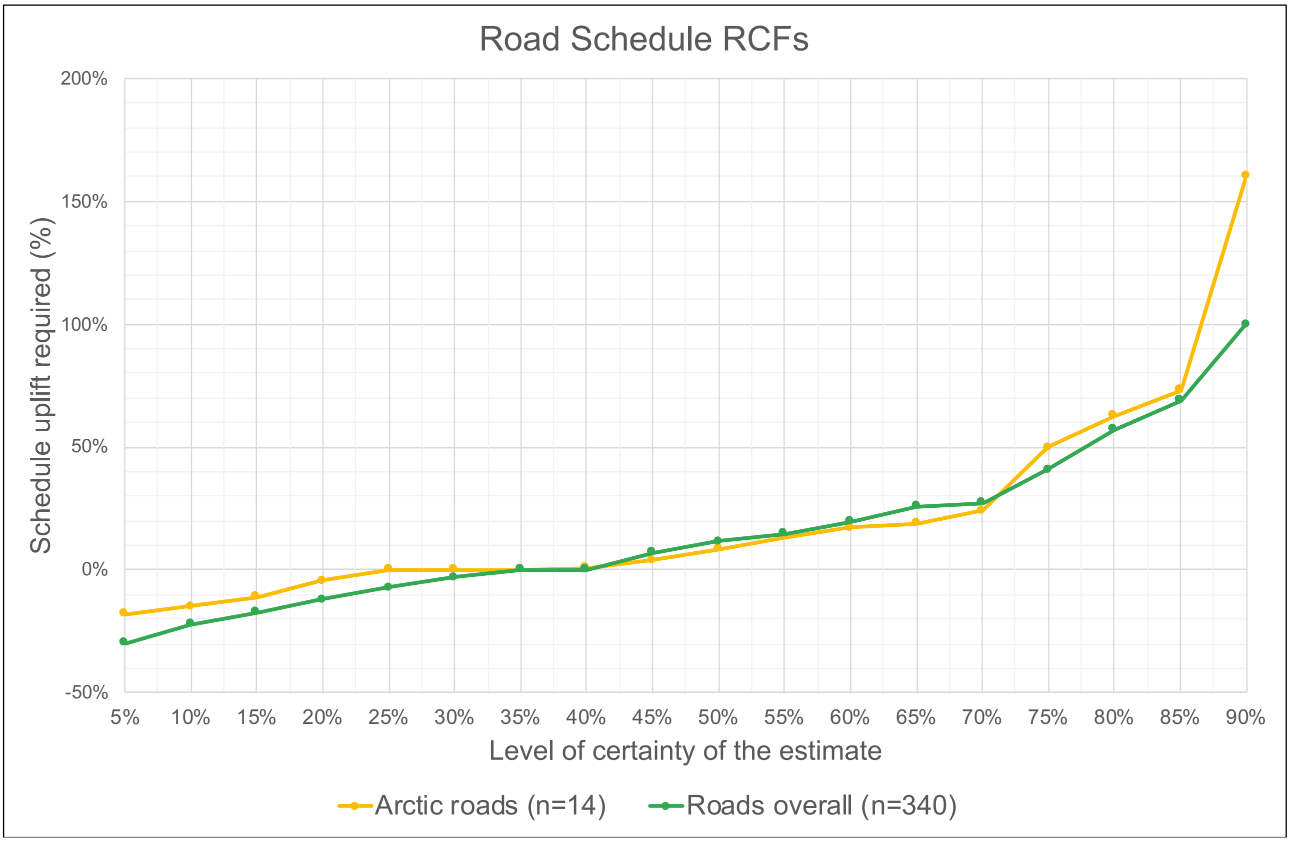
Of the 22 comparable arctic projects, we were able to collect schedule performance data for 14 projects. In the same vein as with the cost analysis, we conducted statistical analyses of the sample of arctic road projects, comparing them to road construction projects worldwide to identify whether the arctic projects differed in terms of schedule performance – i.e., schedule deviation. Here, we found that the schedule risk of arctic road projects was not statistically significantly different from the schedule risk of road projects elsewhere ($p = 0.46$). Box plots displaying the data distributions of schedule overruns for the arctic and worldwide road constructions are shown in Figure 10 below.

Figure 10: Box plots displaying distribution of schedule overruns for arctic roads projects and roads projects overall. A schedule overrun of 1 means that the project finished exactly on time.



Once again, the sample size of arctic road projects used for this test is rather small, which could lead to the non-significant result. However, this time the data do not indicate a higher risk for arctic road projects, with the distributions falling almost on top of each other. On this basis, we recommend that the Arctic Circle Road uses the international distribution of road schedule overruns for its planning. The data show that half the arctic road projects had a schedule overrun of equal to or less than approx. 9%, while half of roads overall had a schedule overrun of equal to or less than 11%.

Figure 11: Probability distributions of schedule overruns for historical arctic roads and worldwide road projects



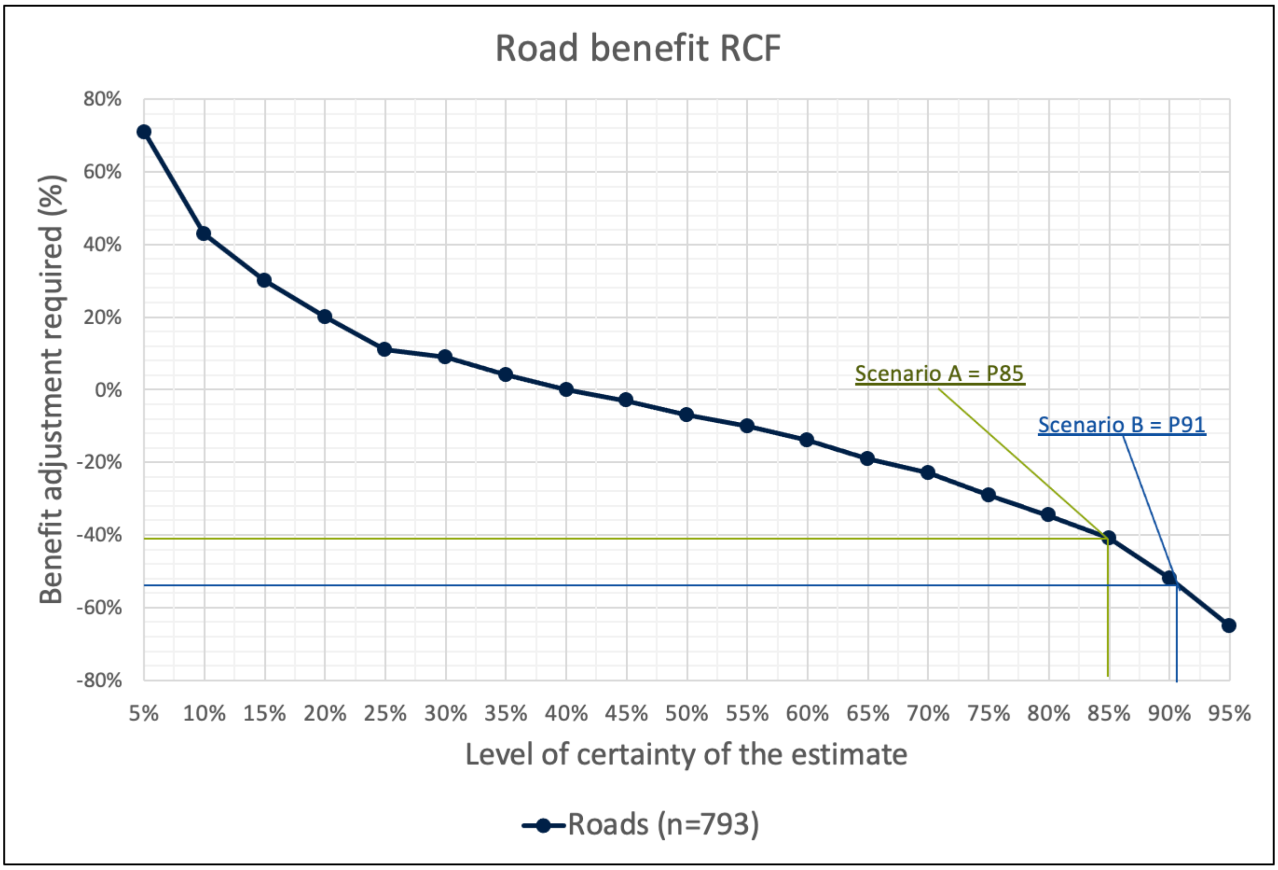
The data shown above are then used to establish the required schedule contingency uplift as a function of the acceptable chance of schedule overrun, i.e. the risk appetite of decision makers regarding schedule. In accordance with the above figure, if decision makers on the Arctic Circle Road project want a 50% chance of finishing the project on or before schedule (P50), the project schedule needs an uplift equal to 11%. On the other hand, if decision makers require a 70% (P70) certainty that the project will finish within schedule, the schedule would require an uplift of 27%.

3.4 Quantitative benefit risk analysis

Due to data unavailability, we were unable to collect quantitative data on benefit realization specifically for arctic road projects. Instead, we therefore compare the project against the benefits realization of the international roads sample, keeping in mind that arctic roads might have a greater benefit shortfall than normal roads based on the literature review.

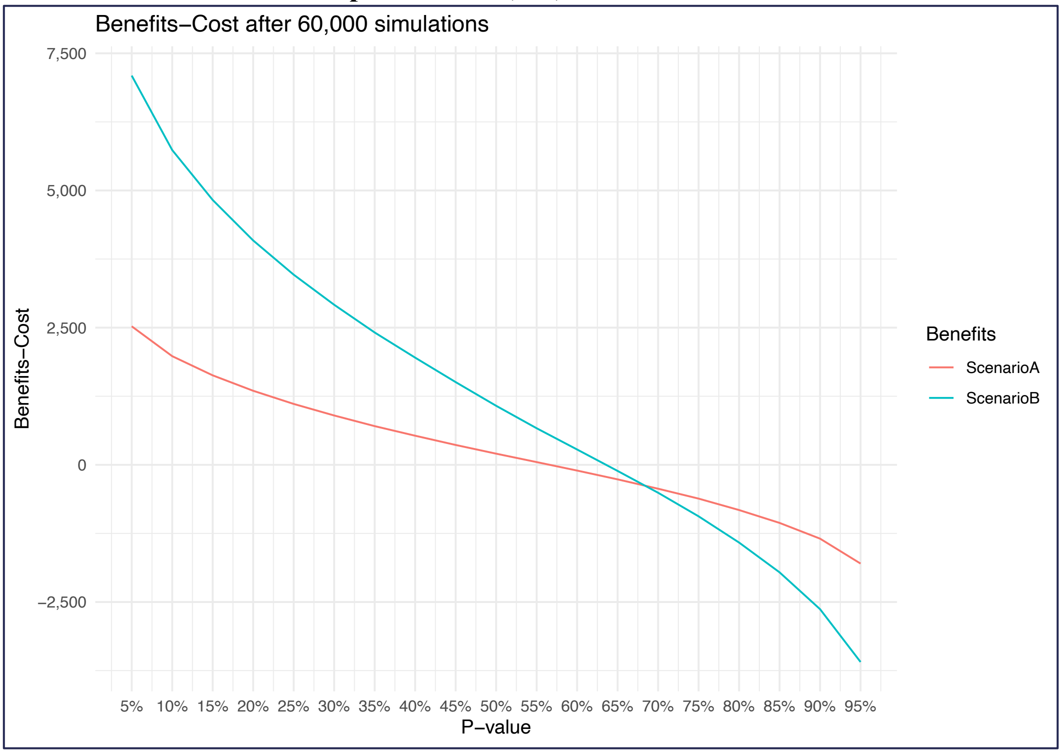
In addition, we have tested the sensitivity of benefits case found in the socio-economic analysis. Here, we identified how much the economic benefits for each of the two listed scenarios could be reduced while the cost-benefit calculation remained positive. The benefits-to-cost ratio remained positive with 41% less benefits for Scenario A and 53% less benefits for scenario B. Thus, the benefits case is robust in that it can sustain a high benefits shortfall while still being profitable. These numbers were compared to the distribution of benefit shortfalls among road projects (n = 793) found in Figure 12 below. Here, we found that 85% of all road projects in the large roads sample achieved outturn benefits equal to -41% or better, while 91% of projects achieved outturn benefits equal to -53% or better. Even if arctic roads have a greater benefits shortfall than other road projects and a real arctic roads distribution would show higher risk, the high P-values indicate a high likelihood of achieving sufficient level of benefits for the benefits-to-cost ratio to remain positive. Especially considering that the benefits found in the analysis are primarily based on tourism, and therefore leaves out a number of other conceivable benefits. When contemplating other benefits, it is important to consider whether labor needs to be imported, in which case the benefits of jobs created would be fewer.

Figure 12: Probability distribution of benefit shortfalls for historical road projects worldwide



Finally, statistical simulation shows that break-even (or better) is 55% likely for Scenario A and 65% likely for Scenario B given the current benefits case of the socio-economic analysis and the distributional cost and benefit RCF risk data, which is shown in Figure 13 below. Note that this model is somewhat conservative since it is based on the full costs displayed in the socio-economic analysis, including costs for further tourism investments such as hotels, employee accommodation, and other tourist facilities, and that not all benefits are included in this model. Therefore, this model extents further than the road construction itself, which only comprises about 34% of the total costs in the analysis.

Figure 13: probability distribution of positive benefit-to-cost ratio based on distributional rcf data on arctic road cost and benefit performance, 60,000 simulations



3.5 Conclusion: Risk assessment in Arctic road projects

Literature review:

- Arctic road construction carries additional risks compared to road construction under normal conditions.
- The additional risk, or Arctic premium, arises from the underlying challenges associated with Arctic road building. These include: difficult geology, building on permafrost, enhanced need

for environmental protection and conservation, and extreme working conditions. Climate change exacerbates these risks and will become increasingly problematic.

- A unique profile of cost and schedule drivers results from these Arctic challenges. They not only increase the cost and schedule of Arctic road building, but also leave the project more prone to the risk of overrun. The main drivers of cost and schedule are: complying with environmental regulations, enhanced community consultation and environmental impact assessment, inefficiencies caused by extreme working conditions, high drainage costs, high transport costs, disproportionate direct and indirect labor costs, difficult to predict material costs, requirement for extensive surveys to reduce risk, and high maintenance costs that will increase as climate change worsens.
- Arctic roads can also be prone to benefit shortfall as a result of unrealized benefits or unexpected trade-offs. The key areas susceptible to benefit shortfall are: socio-economic benefits, road use, and environmental impact.
- In conclusion, Arctic road projects are likely to have a unique and heightened risk profile that warrants a tailored risk assessment. If these risks are not accounted for or mitigated against, the project could be susceptible to high cost and schedule overruns and benefit shortfall.

Cost risk assessment:

- The quantitative cost risk assessment of arctic road projects shows a need for a considerable contingency uplift on top of the base cost estimate for the road in order to achieve particular levels of certainty that the project will complete within budget. A P50 level of certainty (50% chance of cost overrun) requires a risk contingency of 9-14%, while a P70 level of certainty (30% chance of cost overrun) requires a risk contingency of 33-44%. It is unclear how much contingency is included in current estimates on the project and whether base cost estimates are increased to accommodate for the additional uncertainty in arctic regions.
- The cost sensitivity analysis shows that the business case is robust in that much higher construction costs can be tolerated while still maintaining a positive business case.
- The cost estimates may be out of date and will require updating after further surveys and investigations are completed, but the sensitivity analysis shows enough headroom for considerable cost increases, so this is not thought to jeopardize the business case.

Schedule risk assessment:

- The schedule risk (risk of schedule overrun) of arctic road projects is similar to that of normal road construction, although the number of observations for this analysis was low (n=14).
- The quantitative schedule risk assessment of arctic road projects shows a need for a contingency uplift on top of the estimated duration in order to achieve particular levels of certainty that the project will complete within schedule. A P50 level of certainty (50% chance of schedule overrun) requires a schedule uplift equal to 11%, while a P70 level of certainty (30% chance of schedule overrun) requires a schedule uplift of 27%.

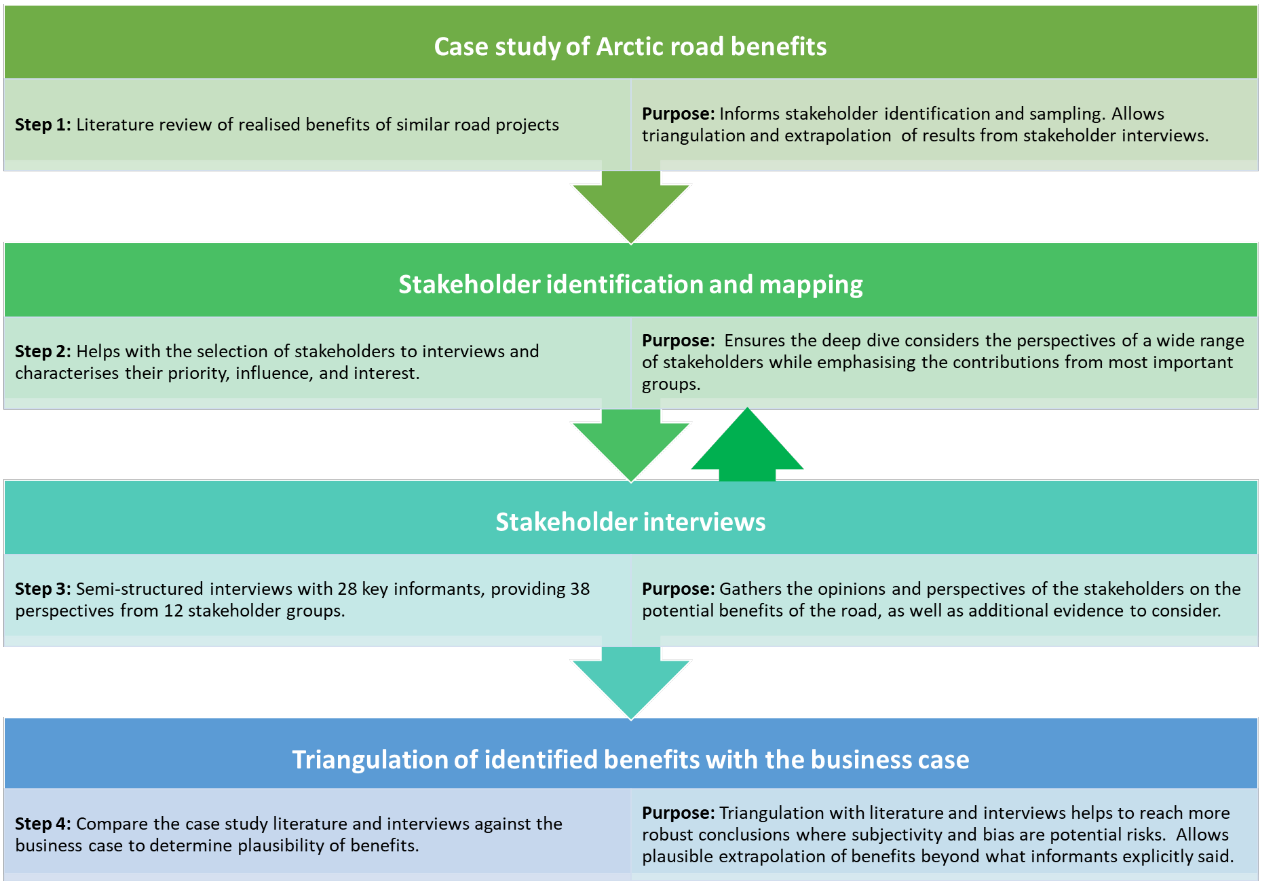
Benefit risk assessment:

- No quantitative benefits data was available to construct an arctic road specific benefits reference class, therefore an international reference class of roads projects was used, which shows that road projects normally experience benefit shortfall.
- The benefits-to-cost ratio of the project benefits case from the socio-economic analysis remained positive with 41% less benefits for Scenario A and 53% less benefits for Scenario B, which indicates that the benefits case is robust in that it can sustain a high benefits shortfall while remaining profitable.
- 85% of all road projects in the large roads sample achieved outturn benefits equal to -41% or better, while 91% of projects achieved outturn benefits equal to -53% or better. Even if arctic roads have a greater benefits shortfall than other road projects and a real arctic roads distribution would show higher risk, the project is likely to achieve sufficient level of benefits for the benefits-to-cost ratio to remain positive.
- Statistical simulation shows that the road is more likely than not to break-even (or better) in terms of benefit-to-cost ratio.

4 Benefit deep dive

This section of the report presents the results from the benefit deep dive according to each step in the analytical process that was used to draw conclusions. These analytical steps are summarised in Figure 14. Further details can be found in the methodology section.

Figure 14: Analytical steps used in the benefits deep dive



4.1 Case studies of realized benefits from other Arctic road projects

In this section of the report, we present examples of benefits that have been realized by selected Arctic road investments. It is important to appreciate that by presenting these case studies, we are not stating that similar benefits or shortfall risks will be realised in the Arctic Circle Road. Instead, we are highlighting where a range of benefits and shortfall risks have materialised in historical and relevant projects.

This information is provided to offer context to the perceived and anticipated benefits of the Arctic Circle Road, so the potential for benefits may be understood. For instance, by demonstrating tourism benefits achieved by the Inuvik to Tuktoyaktuk Highway (limited secondary tourism benefits expected) and the Arctic Coast Way in Iceland (significant primary tourism benefits expected), we are not suggesting that the Arctic Circle Road will materialise as a replica of either one of these case studies. Rather, it shows that Arctic roads have tourism potential, and given the characteristics of the Arctic Circle Road, the tourism benefits are likely to fall somewhere in the middle between these examples.

4.1.1 Broad benefits of the Inuvik to Tuktoyaktuk Highway

The Inuvik to Tuktoyaktuk Highway offers a useful broad summary of the common benefits that can be expected from Artic road infrastructure investment. For a summary of the case study details, please see Figure 5 in the risk assessment section.

In 2014, the North West Territories Department of Infrastructure estimated that with an all-weather road bringing food, goods and fuel north, the cost of living in Tuktoyaktuk will decrease by about $1.5 million a year [26]. After the road was built, the Government of the North West Territories reported that residents of Tuktoyaktuk were benefiting from a reduced cost of living, as goods can now be brought in by ground year-round [33]. However, the authors of this report could not establish the precise reduction in cost of living that had materialised as a result of the rod being built. Residents also have improved access to fresh food, health care, educational, social, and economic opportunities [19]. Reports of increased utilisation of drugs and alcohol, which was a concern related to improving access, have not been found.

In terms of jobs and skills, the Inuvik to Tuktoyaktuk Highway was successful in delivering more than 1000 person years of employment and 40 long-term jobs, plus another 860 person years and 9 long-term jobs in other parts of Canada. Further full-time jobs are expected from tourism. The project also delivered training to approximately 130 individuals as Class 1 and 3 drivers, equipment operators, summer students, and apprentices [19].

Tourism has substantially increased in the region due to the construction of the road and amenities such as a restaurant have opened [34]. While realized figures are not yet available[4], it is estimated that the total number of tourists to visit the Inuvik-Beaufort-Delta region would increase by about 10% to 5,500 tourists per year. The increased number of visitors is anticipated to spend an additional $1,467,500 in the region and create 22 full time jobs. Over the life of the Highway, the net present value of economic effects from tourism is estimated at $21 million with $3.5 million in GDP increases and government revenue for the North West Territories. The effect on the rest of Canada is expected to be $7 million in GDP and $1 million in government revenues [35]. It should be noted that tourism was not a primary driver of the economic business case to build the road (due to extreme remoteness and limited tourist services available), but rather an anticipated secondary benefit.

The road has also reportedly enabled permafrost research [33].

The numbers of travellers on the road in its first year was 15,000, which equates to 41 travellers per day. It is important to note that original estimates were 150-200 vehicles per day. Hence this represents a benefit shortfall. Another key benefit shortfall arises from temporary road closures due to poor road conditions [32]. The road also did not open up opportunities for oil extraction due to a 5-year ban on drilling and may face difficulty serving future port developments owing to weight and closure restrictions [30].

4.1.2 Tourism

Arctic tourism is on the rise [36], in part due to better transportation links. Countries with the most tourism are those with the best access, which are generally Finland, Norway, Sweden and Alaska. A relatively new player is Iceland, which now attracts more tourists than the three northernmost counties in Norway [37].

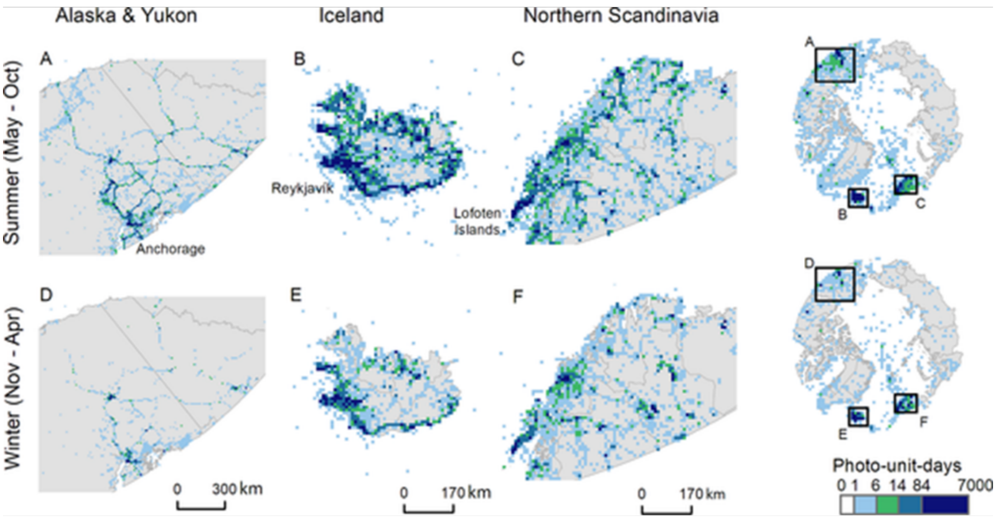
Increasing tourism in Greenland will require investment in infrastructure [38]. Transport infrastructure is the decisive factor for Arctic tourism since travellers are increasingly looking for relatively cheap and easy-to-access attractions [39]. In Canada's Arctic, there are many more tourists in Yukon than in Nunavut because the Yukon has road access while Nunavut does not [37]. The

[4] A completion review of the Inuvik to Tuktoyaktuk Highway has not yet been completed, or is not currently publicly available.

European route E69, which connects Olderfjord and North Cape in northern Norway has enabled mass tourism to Nordkapp with over 200,000 visitors a year [40].

This anecdotal evidence is supported by research that shows spatial patterns of Arctic tourism are strongly governed by air, road and sea access, with few tourists venturing far from populated areas in winter [41]. Tourism appears most dependent of roads and airports, and indeed the main hotspots of tourism fall along coastal roads in Iceland, in the fjords and islands of northern Norway, and in protected areas and along roads in North America (see Figure 15).

Figure 15: Seasonal maps of Arctic tourism (2004-2017) displayed at 10km resolution.



Runge CA, Daigle RM, Hausner VH (2020) Quantifying tourism booms and the increasing footprint in the Arctic with social media data. PLOS ONE 15(1): e0227189. https://doi.org/10.1371/journal.pone.0227189
https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0227189

4.1.2.1 Tourism on Iceland's Arctic Coast Way

Iceland's Arctic Coast Way is an important and relevant example for the Arctic Circle Road because tourism was the key economic argument for the road, and it shows how an Arctic road can both open up tourism, as well as be a tourist destination in its own right. According to the Independent Newspaper (UK) "Iceland's first official touring route opened last summer (2019), eager to lure tourists from the national Ring Road and on to paths less travelled. Hugging the northern coastline around six distinct peninsulas, this seductively monikered 560-mile (900km) drive steers you through thrilling extremes. Fjords, glaciers, mountains and waterfalls are all in plentiful supply, people less so – and therein lies its appeal" [42].

Iceland's Arctic Coast Way is now prominently featured in high profile tourist guides such as the Lonely Planet [43], where it is ranked in the Top 30 Destinations in Europe (2019), owing to the many attractions that can be visited along the route [44]. The increased access and investment along the Arctic Coast Way have reversed the declining fortunes of traditional villages which had largely been abandoned as the fishing industry declined. Now villages such as Siglufjörður have booming tourist industries with renovated docks, up-market restaurants, and boutique hotels, and a craft brewery [45].

However, increases in tourism are not without their drawbacks. Iceland now gets four times their population visiting every year causing increasing pressure on infrastructure, the housing market and the environment [37]. A report on Arctic regions and its concerns, threats, and potential challenges found that "increasing tourism activities are disturbing the wilderness and wildlife of the Arctic region. For example, over-flights are disturbing the birds and mammals and kerosene released from the aircraft is residing on the ecosystems of the Arctic. Similarly, cruise tourism is disturbing the wildlife and polluting the Arctic water. Land based tourism has the potential for the greatest damage owing to the permanent facilities for transport and accommodation which it requires. As a whole, increasing tourism has potentially harmful results, though good planning can go a long way in mitigating these results and it is possible to over stress this potential challenge. [46]"

4.1.3 Community development

As a counterfactual to exploring the benefits of road development, we may also consider a case study of road access removal and its impact on Arctic societies. In many Arctic regions, communities can suffer from isolation due to seasonal inaccessibility, especially in summer when ice roads melt. Ice roads therefore present a vital component of transportation infrastructure and local mobility during the winter season and are an important connection option for remote communities.

A study in the North Dvina river delta in arctic Russia found that shorter ice road seasons due to climate change have led to economic and social risks by threatening safe mobility and by negatively impacting communities' industrial and socioeconomic development [47]. Changing mobility patterns due to unpredictable ice road seasons affect not only the viability of the populations, but also local attractiveness for residents, tourists, and entrepreneurs. Ultimately, it is argued that decreasing mobility in this area of Russia will lead to out-migration and a vicious cycle of decreasing transportation services that, in turn, will decrease the attractiveness of the region and lead to further outmigration.

Similarly, a report on sustainable society development in Arctic cities [48] found that decay of roads due to melting permafrost creates challenges for the sustainability of smaller settlements and the region's overall economic development. It is therefore important that transport possibilities are functioning and sufficient, and improvements are therefore important.

In this case study of Arctic cities [48], accessibility and infrastructure are considered vital to the peripherally located Arctic cities. Norwegian cities have benefited from massive government investments in regional infrastructure, made possible by the Norwegian Oil Fund. For example, in Narvik (Norway), the ice-free port, international railway and road have been key drivers for growth and made Narvik a transport and trading hub of the region. The University College, some high-tech businesses, and hydropower companies make Narvik a vital technological hub in the North.

Despite being the best-connected city in Greenland, it was found that Nuuk had the least developed transport infrastructure among the case study cities and was particularly challenged in terms of its development by long and costly travel fees. Overall, a conclusion on best practice political strategies was that cities which actively involve and seek to meet citizens' demands in terms of urban planning (roads, water connections, urban renovations) are more attractive for newcomers and retain existing population to a higher degree. However, Nuuk scored "low" on its accessibility and urban planning outcome assessment [49]. This may explain why Greenland experienced relatively slow growth in the prior ten years before the report was published (2013), increasing the gap between Greenland and other countries in the Arctic region.

However, it is also important to note findings from the Business Index North report which compares level of sustainable development for 14 regions in Arctic Europe, including Norway, Sweden, Finland and Russia. According to a Nordland County Councillor (Norway) the report demonstrates that several regions experiencing economic growth also observe a negative trend in population development. Young people migrate out from the region". This suggests that economic development in the Arctic does not necessarily mean an improved economic situation for the local population. A potential reason for this "Arctic resource paradox" is that Arctic regions lag far behind national averages in terms of education. Therefore, it is concluded that investment in education is a prerequisite for economic development in Artic regions. Thus, improved infrastructure alone will not be sufficient. This caveat to the community development benefits of roads is especially pertinent to Greenland given that Nuuk had the lowest educated population of all Arctic cities in the Ramboll report [48].

4.2 Stakeholder identification and mapping

The performance of megaprojects is closely linked with stakeholder engagement and management. If not understood and managed properly, stakeholders can introduce risk to a project in terms of conflicts, inefficiencies, and delays. To reduce risk, an understanding of the different stakeholder, their interests, and the power relationships around a project as well as the competing and often conflicting priorities and goals, is required [49].

The following stakeholder mapping provides an overview of the numerous parties involved in the Sisimiut to Kangerlussuaq Road Project, including the key stakeholders, their requirements and expectations, perceptions on the consequences of a no-build scenario, and assumptions for success.

Based on a list of approximately 50 potential key informants, stakeholders were divided into 14 stakeholder groups, as shown in Table 5.

Table 5: stakeholder groups in the planning phase of the road project

Stakeholder groups
Accommodation providers
Air traffic representatives
Environmentalists
Freight companies
Government of Greenland
Investors
Local business representatives
Local residents
Military
Municipality of Qeqqata
Natural resource interest groups
Science and research representatives
Telecommunication
Tourism providers

4.2.1 INFLUENCE/INTEREST MAPPING

To determine the influence and interest of the various stakeholders and thus how they should be considered, we have mapped them onto a commonly used framework called an influence-interest grid [50]. This stakeholder mapping is presented in Figure 16. This mapping is a snapshot of the situation in the current stage of the project and the relationships are likely to change throughout the project life cycle.

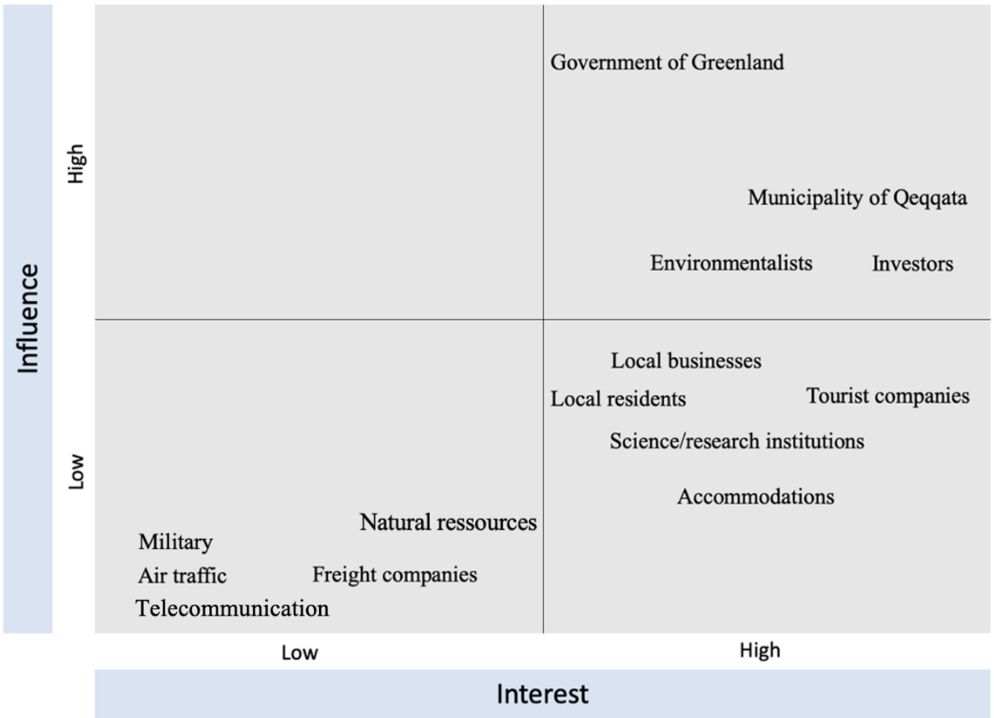
Placed in the top right corner are key stakeholders with a large influence and interest in the project. Besides the local and national government, both environmentalists and investors have a high influence on the project. This is because possible environmental derivative effects are considered by all stakeholder groups as the main disbenefit. Concerns regarding environmental issues are thus highly influential, especially during the planning phase of the project. The presence of investors is considered important for many stakeholder groups because they are key to the project becoming an economic success, and thus give the investor group has a high influence on the project. Stakeholders in the high influence-high interest quadrant are the most critical to project decision making and therefore need to be managed closely.

In the bottom right corner are stakeholders with lower influence but high interest. These stakeholders include local businesses, smaller potential investors in accommodation and tourism services, local residents, and the science and research community. These stakeholders are key beneficiaries of the project but have less influence over it. Therefore, they should be kept informed.

In the bottom left corner are stakeholders with lower influence and lower interest in the project. These include air traffic and supply line/freight companies. It is important to note that while their current level of engagement with the project limits their influence, they are still critical for project success. Therefore, if they were to engage more closely with the project and take a position on a build or no-build scenario, they would move into a high influence quadrant. During interviews, these stakeholders confirmed that they currently have low influence and interest in the Arctic Circle Road. However, they should be monitored closely in case they change their position.

There are no stakeholders currently in the high influence-low interest quadrant, but if stakeholders move into this quadrant, they should be kept satisfied [50].

Figure 16: Influence – interest grid with the various stakeholder groups.



4.3 Perceived benefits per stakeholder group

Please note that this section on perceived benefits per stakeholder group presents the opinions of direct stakeholders interviewed as part of this risk assessment. These opinions were considered by the authors and interpreted alongside other data previously presented. The author's conclusions are presented in the following section.

All stakeholders that were interviewed were either neutral or in favor of the road project, and there were no conflicting or divergent opinions on the key themes presented below. Development in tourism was mentioned by all respondents as an expected benefit from the road project and is considered the main benefit by all three stakeholder quadrants. The following section presents the perceived and anticipated benefits of the Sisimiut to Kangerlussuaq Road Project by stakeholder group.

4.3.1 High influence - high interest stakeholders

Government of Greenland

The government are a key stakeholder as a matter of law, and as an expected co-financer of the road. Opinions within the Government vary. Some departments are more convinced than others that the road will create economic benefit through tourism and other drivers. Respondents considered that there would be synergy between the road and the Government's overall airport investment strategy because the expanded airports at Nuuk and Ilulissat would increase the potential for tourist to visit Greenland. Respondents thought that the improved accessibility and tourist experience provided by the new road may then encourage tourists to stay longer in Greenland so that they can visit Sisimiut and Kangerlussuaq and explore the Arctic Circle Road and its experiences. Thus, the Sisimiut to Kangerlussuaq road project could reportedly leverage the investments in airport infrastructure at Nuuk and Ilulissat.

However, other individual and departments within the Government question whether the road can really deliver the benefits outlined in the business case. They stated that if there was a benefit shortfall, the required expenditure on road construction and maintenance may then not be a good investment because, in their view, the road must have a net economically beneficial effect. To this end, they point out that the road may not be sufficient to retain investment, people and skills within Sisimiut and Kangerlussuaq, partly because they may instead be attracted by the airport investments planned at Nuuk and Ilulissat. These respondents stated that if this was the case, there may even be a shortage of labour to build the road. Some individuals also question the economic benefits predicted in the business case because the proposed investments would not be committed until the road is approved. Therefore, they did not consider such investments as guaranteed.

These opinions point to the assumptions that for the road to be a success, the project needs to be locally anchored and provide strong evidence of investment commitment.

Municipality of Qeqqata

The Municipality of Qeqqata expect the road to create economic development in the region as well as the country as a whole. They reported that the economy in the region is currently based on the fishery sector and considered that this dependency on a natural resource was unstable. They expected the derived effects from the road to help diversify the economic foundation of the region and therefore improve economic stability and sustainability.

The road is primarily expected to create value through tourism and the science and research sector. For tourism, respondents thought that the road would provide reliable and cheap transport infrastructure which they expected to attract more tourists and associated private investment. Since they considered that the private investment would be contingent on the road being built, the road would therefore be essential for investors to commit to tourism investments in the area. For science and research, respondents thought that the road would open up easier access to the icesheet and make it easier and cheaper to conduct Arctic research. The Municipality also consider the road important for community development by reducing isolation and offering recreational opportunities for local residents. They stated that this would help address the expressed concerns of Greenlandic communities, many of whom have never been outside their hometowns.

The Municipality did not report any significant downsides to the road being built but thought that there would be serious risks with a no-build scenario. This is because they consider the road to be the only possible way to develop the regional economy. Without a road, respondents thought that the tourism sector would be too small to support the economic diversification of Sisimiut and Kangerlussuaq, and investments in tourism would not be made or made elsewhere. Accordingly, if the road does not get built, respondents from the municipality expected that the economy in the region would slowly decline.

Respondents pointed out that the risk of regional economic decline is exacerbated by the new airport strategy which would attract any remaining investment possibilities away from Qeqqata in favour of Nuuk and Ilulissat. As a result, they felt that the new airport strategy had created a serious uncertainty about the continued existence of the whole region. Respondents expected that the possible decline in international flights to Kangerlussuaq airport would result in job losses and outmigration of residents in the area. Some investors are already reported to be leaving the area. An example is Albatross Travel who wanted to build lodges in 2015. When the plans for the airports came, they withdraw their investment. The airport strategy has also reportedly raised concerns that large government run institutions in Sisimiut may be moved to Nuuk.

This led the Municipality to state that the key assumption for success would be that Kangerlussuaq Airport remains open to commercial traffic. They also felt that direct flight services would increase the tourist appeal for the region. Other factors they considered important were that the road should be capable of bus and lorry transport so that tourists and goods could be transported in bulk. Ideally they wanted the road to be open most or all of the year so that tourism and associated economic opportunities would be less seasonal.

Environmentalists

Individuals from the environmental stakeholder group were predominantly positive about the road development. In their view, by making it easier for people to visit protected areas, including the UNESCO site and the proposed National Park just North of Kangerlussuaq, the road would help create awareness and support for the conservation of local nature and cultural heritage. Environmentalists considered tourism to be particularly beneficial because they felt that it would make investing in conserving the UNESCO site economically beneficial (nature would become an asset), especially through bespoke ecological tourism. Respondents also reported that the increased accessibility offered by the road would enable better and cheaper surveillance of the UNESCO area.

Environmentalists' key assumption for success was that Kangerlussuaq Airport remains open to commercial traffic so that visitors could easily reach the area. They did raise the risk that the road and associated increase in tourism and hunting could disturb the flora and fauna, including reindeer breeding, if not well regulated. However, they felt that if the road investment was accompanied by an environmental management plan, including traffic regulations and provisions for a park ranger, such risks were manageable.

Investors – including smaller tourism and accommodation providers

Potential investors are a diverse stakeholder group. Some are more influential and are integrally involved in the business case development and associated decision making. Other investors include smaller tourism and accommodation providers that are very interested in the project from a beneficiary perspective but have limited influence. Since this variation in influence is a continuum, it is not possible to describe these groups separately. Therefore, we present the views from these groups in a single section. This does not affect the outcome of the analysis because they all had similar perspectives on the road development. It should just be noted that not all viewpoints will have the same influence.

Investors were overwhelmingly positive about the road development because they felt it would open the whole region for tourism. They considered the road to be a “reason to visit” in its own right, with driving the Artic Circle Road being sold as a primary attraction/experience. Similar to the Government of Greenland, Investors considered the road to be synergetic to national airport investments because the road would give potential international travellers to Nuuk and Ilulissat another reason to visit Greenland. Thus, they thought that the road may also encourage investment and economic growth in Nuuk and Ilulissat.

Investors also thought that the road would lead to increased and more dependable tourist spending. They expected that visitors who normally transit through the region would be more likely to stay for longer so that they could visit more of the tourist attractions that the road offered. Respondents also thought that the road would also allow a longer tourism season, ideally attracting tourists to Kangerlussuaq all year round. This would reportedly make it viable for more permanent local jobs to be created, rather than just importing seasonal employees during the short summer months, as is currently the case.

The expected increase in tourism numbers, duration of stay, length of season, and associated spend was then considered by respondents to make it economically worthwhile to invest in tourist infrastructure and services. In total, our interviews with potential investors identified approximately 365 million DKK in accommodation investments, and 50 million DKK in a tourist experience. While not certain, several investment numbers were accompanied by investment case drafts which suggest considered intent to invest should the road be built. Other larger investments were mentioned but were considered too speculative to quantify at this stage because they were not accompanied by any business case information.

The business rationale for accommodation investments reported by respondents was that the road will encourage more mainstream tourism from families and high-end visitors. As opposed to the traditional low budget hikers, investors expected these tourists to be more likely to demand higher quality accommodation and be willing to spend more money on comfortable facilities. The expectation of increased length of stay and longer tourist season also reassured investors that demand would be sufficient to warrant scaling up their operations.

However, investors were clear that a transparent approval process was a pre-requisite for their investment. They reported that until they have clarity on the government decision making process to build the road, they would be unwilling to make the aforementioned investments. As with other stakeholder groups, investors also emphasised that the continued commercial operations of Kangerlussuaq Airport would be important for project success. Other factors that they said would support success included marketing and communication for Greenland tourism, a clear nationally coordinated tourism strategy including how the planned road supports tourism and what secondary infrastructure is required, and a minimum road speed of 60km/h.

Investors did raise the concern that mass tourism, especially from cruise ships or large tour buses, could put too much pressure on Kangerlussuaq or Sisimiut, resulting in them becoming “display” towns that benefit tourism but not local residents. However, they saw the fundamental risk to the community to be a no-build scenario. In this case, they expected tourist numbers and investment to drop below current levels which would ultimately lead to economic decline and community collapse.

4.3.2 Low influence - high interest stakeholders

Local businesses

Local businesses were strongly in favour of the road, citing several benefits and few drawbacks. The key benefit that they anticipated was improved quality of life for the community through more reliable and affordable transport options. It was felt that this would make the towns more attractive places to live and work, and thus improve the labour market. They also reported that more reliable freight and transportation of goods, as well as better access to services like motor testing areas would also help business operations and lower costs. These benefits would reportedly result in local business development if the road was built, including the establishment of an electrician and the opening of three new stores in Kangerlussuaq.

Similar to other stakeholders, local businesses considered the key risk to the local communities to be a no-build scenario which they said would result in loss of investment and economic decline. For the road project to be a success, they too stated that Kangerlussuaq airport must remain open to commercial traffic and that the road be open all-year round. They also said that safety regulations and traffic surveillance should also be put in place.

Local residents

Local residents were, on the whole, in favour of the road development. This was largely due to the improved quality of life that they expected the road to bring. The road was seen as key to addressing feelings of isolation which was thought to be causing out-migration and population decline, especially amongst the younger generation. Impact on the cost of living was also important; improved transport infrastructure was expected to make groceries in Kangerlussuaq 20% cheaper and if new business opened up they reported that this could result in reduced costs through healthy competition. Local residents also expected the road to offer improved access to hunting grounds and more recreational activities.

Some local residents were wary of the level of investment required to build and maintain the road and suggested that the socio-economic benefits may be overstated because people in Greenland live a unique lifestyle. As such, they said that a prerequisite for road success would be a strong business case. Residents were also concerned about the risk to the environment, citing environmental issues such as pollution in lakes, disturbance of caribou breeding grounds, increased trash and other negative impacts from tourists. However, others felt that the road was necessary to prevent economic decline.

In terms of assumptions for project success, local residents re-emphasised the need for the road to be economically sustainable, as well as a clear decision from the government that would enable associated investments to be made. They also echoed other stakeholders regarding the need for traffic and safety regulations.

Science and research

Stakeholders from the science and research community were also in favour of the project due to the increased research site accessibility that they thought the road would offer. The area along the road reportedly provides rich opportunities for studying the Arctic environment in a variety of fields because the climatic zones change along the length of the road from coastal climate, to mainland climate, to ice cap. The area is also reportedly important for research because it enables access to the largest ice-free area in Greenland between Sisimiut and Kangerlussuaq, while the Kangerlussuaq-end would enable better monitoring of permafrost degradation, which is an issue of national and global importance. Research on climate change is already taking place at Kangerlussuaq but scientists thought that the improved accessibility would open-up previously inaccessible research possibilities. They also reported the potential for more commercial research activities, including those requiring refrigeration or testing in cold climates.

Given the importance of the research sites and potential for inter-sectoral research, scientists expected the road to facilitate international research collaborations and research connecting the UNESCO site to the proposed National Park. In additional to the scientific value of this research, they also anticipated the potential to generate local revenue through the provision of services to research groups.

Respondents also stated that the road would enable more scientific research by reducing the cost of transportation. This would reportedly make it cheaper to freight equipment and conduct field studies in the area, which respondents suggested may then support further university research and associated market growth and revenue. For these benefits to be realised, scientists stated that the road must have two lanes large enough for goods vehicles and buses. The risk identified by scientists was the potential for environmental damage, which led them to say that regulation of tourism would be required.

4.3.3 Low Influence - Low Interest Stakeholders

The authors of this report found it difficult to engage with representatives from the low influence-low interest group, presumably because they are low interest stakeholders. Stakeholders in this group include: air traffic representatives, supply lines/freight industries, military, and natural resource interested groups such as fishing, farming, and water companies, and energy. Representatives from the natural resources and military did not respond to our requests for comment.

The air traffic and supply lines/freight industries are the most critical stakeholders because while they currently have little direct influence and interest in the decision-making process, they are reportedly critical to the road's success in terms of providing the transport services upon which increased accessibility, tourism and the shipping of goods depends (as pointed out by most stakeholders). Should they take a position on a build or no-build scenario, including what services they would aim to provide, they would move into a high influence quadrant.

While we were not able to establish their intentions or investment plans should the road be built, it is presumed that they would offer services in accordance with demand. Therefore, if the road construction generates demand for air transport and supply lines/freight as expected, these industries would probably respond from an economic perspective to meet this demand. This assumption requires further investigation with the associated companies, but it is supported by the findings that both industries are generally supportive of the road. The air traffic industry sees opportunities in terms of greater connectivity in national infrastructure, including the road's synergy with the Nuuk and Ilulissat airport investments, and the supply line/freight industry considers the road to provide greater flexibility in terms of transport options and the potential for more business through higher tourist and resident consumption of goods.

The government owned Telepost would also be an important service provider, if there is a need for new telecommunication, IT, and postal services along the planned road. In interviews with two respondents from Telepost, they stated that at the current stage of road planning they did not really see how the road could create benefits for their business. Equally, they saw no drawbacks. The provision of infrastructure for telecommunication and IT along the road is not considered to be a positive business case, although they still might be obligated to do so under universal service provision arrangements. They said that this would be a political decision.

4.4 CONCLUSION: TRIANGULATION OF IDENTIFIED BENEFITS WITH THE BUSINESS CASE

In this concluding section of the benefits deep dive, we explore the extent to which the benefits case studies and interviews are aligned with the business case for the Sisimiut to Kangerlussuaq Road Project. Where alignment is observed, the authors may conclude that the arguments in the business case are plausible from a qualitative perspective. Examination of the robustness of the business case from a quantitative and risk perspective is presented in the previous sections.

Overall, we see clear alignment between the arguments made in the business case and the perspectives and viewpoints expressed in the interviews. Tourism is clearly considered as the primary beneficiary industry for the project, with the road providing several key drivers. These include, providing cheaper and more flexible transport options between Sisimiut and Kangerlussuaq, improved access to areas of touristic interest, and evidence of long-term commitment to transport infrastructure.

The argument that tourists would be attracted to the area if the road was built appears well founded. The interviews closely align with the business case in terms of an expectation of greater numbers of tourists, longer duration of stay, and longer or all-round tourist season. Both point to the road opening more tourist experiences throughout the year by offering a combination of complimentary attractions that could occupy tourists for several days. The literature review also found that tourism appears dependent of roads and airports, and indeed the main hotspots of tourism fall along coastal roads in Iceland, in the fjords and islands of northern Norway, and in protected areas and along roads in North America.

Iceland's Arctic Coast Way is an important and relevant example for the Sisimiut to Kangerlussuaq Road Project because it shows how an Arctic road can both open up tourism, as well as be a tourist destination in its own right. The case studies of the Inuvik to Tuktoyaktuk Highway have also shown that tourist benefits have materialised when Arctic roads are built and are thus plausible. Given the nature of tourist infrastructure and sites available, we would envision the Arctic Circle Road tourist potential to sit somewhere between these two cases, but with closer similarity to Iceland given the road's primary economic purpose of tourism, proximity to an airport and port, and sites of tourist interest available. However, it is important to consider that other factors such as the higher cost of living, comparatively more expensive domestic transport options, and longer international flights from Europe that will also factor into tourist potential. While the COVID-19 pandemic is currently a major barrier tourism, it is expected that associated travel restrictions would be eased and tourism more normalised by the time the Arctic Circle Road would be open.

Both the interviews and business case highlight the potential synergy between increased international travel capacity at Nuuk and Ilulissat and the popularity of Kangerlussuaq and Sisimiut as tourist destinations. While this seems plausible, strategic dialogue between interested parties will likely be required to leverage potential synergies and overcome any barriers or concerns. For instance, there are academically published concerns that the continued operation of Kangerlussuaq Airport could negatively impact on the cost benefit ratio of the new airport investments at Nuuk and Ilulissat [51]. Such concerns, regardless of their technicalities, would need to be allayed and plans put in place to promote complementarity over competition if synergies are to be realised. A simple example would be airlines providing multi-stop options or linking of domestic and international flights, so that they support each other's benefits, rather than competing or acting independently.

It is notable that the interviews did not raise the synergy between Sisimiut's new port and the planned port at Kangerlussuaq. This may be due to the limited sample size of our interviews and inability to engage with the shipping industries. However, we found evidence of similar effects of road development and improved transport infrastructure on tourism within the literature. This has been anecdotally shown in case studies and empirically proven in research. The most relevant example is from Iceland where the combination of improved airport infrastructure, increased cruise ship capacity, and the construction of an Artic road "experience" has contributed to a tourist boom.

Both the interviews and case studies agree that these drivers would provide sufficient reassurance of long-term growth in tourism for businesses to invest. Accommodation and tourist services were clearly the most likely investments, and both sources argued that this would lead to a positive feedback loop whereby investments would attract more tourists. The argument that the road would allow mainstream tourism and therefore demand for higher-end services was also confirmed in interviews. While we could not independently confirm the quantified planned investments presented in the business case, we were able to establish clear considered intent, in the form of investment case drafts, from investors among our sample. There was also speculation of potential larger investments. At this early stage of road planning, this is the extent of business consideration that one would expect, given the current uncertainties and long-time horizon to the road being opened. The connection between road development, tourism, and business investment is supported through the case studies and literature, and therefore appears plausible. The Icelandic case study provides the most impressive example, but even where tourist activities are more limited, such as on the Inuvik to Tuktoyaktuk Highway, tourism and investment have followed. However, for business investments to be aligned with road planning decision making, strategic dialogue will be required (see following paragraphs).

Although not explicitly stated in the interviews, arguments from the business case that the tourism investments have the potential to generate significant public revenue appear well founded. This supposition is supported by evidence from the case studies that show increases in tourism through road development have increased income in local communities, as well as generated regional revenue and contributed to national GDP. However, a revenue analysis, including more precise quantification of potential investments and benefits would be needed as part of an updated business case that would usually be required before a final decision to build the road is made. This decision point would normally occur after further investigations have been made to confirm a single preferred option for the route and surveys that allow for an updated firm estimate to be completed.

The second most emphasised benefit in the business case is development of the science and research industry. While stakeholders agreed with the business case regarding the road's benefits for Arctic research, none mentioned the potential for commercial research. However, this may be due to our limited sample size and lack of respondents from the industrial research sectors. Further work may be required to establish commercial research intentions should the road be built. Nonetheless, the argument that the road will benefit Arctic research is plausible. The literature frequently emphasised the need for more Arctic research, especially on permafrost, and the case study of the Inuvik to Tuktoyaktuk Highway shows that where roads provide access, Arctic research follows.

Other benefits may be derived from industries outside the tourism and research sector, such as natural resource interested groups, but currently there is too little evidence able to comment further.

Perhaps surprisingly, the business case did not prioritise the potential of the road to provide socio-economic benefits. Although an increase in jobs and income were mentioned, stakeholders also emphasised the value of the road in terms of reducing isolation, decreasing cost of living, and improving recreational and other community activities. Indeed, some felt that without the tourism-derived economic stimulus and improved transport infrastructure provided by the road, the region was doomed to decline and suffer outmigration. This would be exacerbated by infrastructure investment and job creation in other regions.

All these arguments are supported by the literature and case studies which show that transport infrastructure is essential for community development, and where this is withdrawn, communities have declined and the youth have left. The Inuvik to Tuktoyaktuk Highway case study, and review of tourism impacts especially in Iceland, clearly show that improved transport infrastructure coupled with tourism can generate long-term jobs and reverse the decline of isolated communities. This is primarily achieved through local business investments that have been shown to follow the demand created by road traffic and tourism. We also see evidence of improved infrastructure significantly reducing the cost of living (projected, but unconfirmed at approximately 8000 DKK per resident of Tuktoyaktuk), so the business case arguments on this matter are again plausible.

Given the link between transport infrastructure and population demographics, it is understandable why there are concerns that population decline in Kangerlussuaq may be precipitated by the potential decline in air traffic at Kangerlussuaq [52]. While it is possible this may reduce resident-derived benefits of the Arctic Circle Road, it is unlikely to undermine or negatively impact the benefits-to-cost ratio because the business case almost exclusively focuses on tourism-derived benefits. Therefore, the socio-economic benefits appraised in the business case are unlikely to be sensitive to changes in local resident demographics.

Problematically, establishing the security required for businesses to invest in the region becomes complex when Government stakeholders are considered. This is because the Government appears unwilling to commit to the road development until investments are committed to by the business community. Conversely, the business community is unwilling to commit to investment until the Government takes a final decision on the road development. In this catch-22 situation, close strategic dialogue and joint planning are required to provide clear signals of intent at different stages of decision making. This will provide parties with incremental confidence to take a decision.

At this immature stage of decision-making, it would be unusual for the government to require rigorous evidence of firm commitment for investment. Instead, we would expect to see clear signals of intent from both parties to progress with further investigations that would allow the project to progress to a more mature stage. It is the authors opinion that investors have provided sufficient favourable evidence through the business case to warrant investment in the further investigations required. Once further investigations are undertaken, this should provide the business community with the confidence they require to invest in more robustly evidencing their commitment. At this point, the aforementioned revenue analysis as part of an updated business case, including validation of potential investments and benefits, may be completed before a final decision is made.

It is hoped that this report will provide key stakeholders with the information they require to engage in this strategic dialogue and determine a future course of action. At this stage of planning and contention, it may be helpful to focus strategic dialogue on the primary high influence stakeholders so that progress and agreement between these parties can be made more rapidly. Once there is clarity among these high influence stakeholders, dialogue and engagement could be extended to other high interest but less influential groups of stakeholders. To facilitate strategic dialogue, a roadmap to decision-making could detail out expectations from key parties that are required to progress to the next decision-making gate.

However, a firm commitment to the project was clearly not the only prerequisite for private investment and associated success of the road. Continued commercial operations at Kangerlussuaq Airport was considered by all stakeholders to be critical for tourism development and most other benefits. Although initially uncertain, the Government is now committed to keeping the airport open to international traffic. Together with the Danish military, the Government will ensure that a 2500m runway will be maintained and kept open to both the Danish military and commercial flights [53].

This recent Government decision provides much needed clarity on the future of Kangerlussuaq Airport and therefore satisfies investors basic requirements. However, it will still be important to closely engage with the air traffic industry, particularly regarding the level of commercially viable traffic they require to maintain or expand operations to meet tourism requirements. While we were able to establish that air traffic representatives were broadly supportive of the project, and it can be assumed that they would respond to any increase in demand, this represents a critical gap in the evidence required to take future decisions.

Similarly, we found little evidence to establish the intentions of supply line and freight companies, except for their broadly positive view of the road project. Determining these stakeholders' position in the event of a build or no-build scenario will also be important given that several of the road benefits are contingent on their service provision. The criticality and government leaning toward provision of Telepost services along the road also needs to be understood.

The various sources of evidence also highlight that other important decisions need to be made at the road design stage in order to realise expected benefits. Principally, as reported by stakeholders, these include that the road can remain open for all or most of the year, that it is a 2-lane highway capable of accommodating buses and lorries, that vehicles can travel at up to 60 km/h, and effective traffic and safety regulations are put in place. All three cost estimates reviewed in this risk assessment include these requirements, therefore their planning appears fit for purpose.

Complementary measures could also help to increase the magnitude of benefits and prevent disbenefits. These include environmental protection and conservation measures to mitigate against potential damage to the environment. Coordination between the government and private investors, and strategic planning and actions to encourage tourism and other industries' interests are also needed. These requirements are normal in a business-friendly environment and align with the Government tourism strategy, so we can expect them to be satisfied.

5 FINAL CONCLUSIONS

This report investigated the feasibility of the proposed Arctic Circle Road project. Where uncertainties existed in our analyses, this risk assessment took a conservative approach.

There is sufficient supporting evidence from the stakeholder interviews, case studies, and literature to conclude that the primary tourism benefits presented in the business case are plausible. The investment is also likely to satisfy a local need. Other benefits including associated investment, lower cost of living, and enabling science and research are also supported. Currently, the economic appraisal focusses narrowly on tourism benefits, so there might be scope for further socio-economic analysis, including other local industries and research sectors.

In general, the assumptions that are required to hold for benefits to be realized appear to largely be in place. Potential demographic change in Kangerlussuaq is unlikely to affect the benefits-to-cost ratio of the socio-economic analysis appraised due to the almost exclusive focus on tourism derived benefits.

Based on our statistical analysis, we find that the Arctic Circle Road is likely to achieve a positive benefit-to-cost ratio, even under a conservative scenario. It would only have to perform better than 9% of all road projects to maintain a positive benefits case.

The quantitative cost and schedule risk assessments of Arctic road projects show a need for budget and schedule uplifts on top of the base estimates depending on the risk appetite of decision makers.

While the cost estimates may be out of date and not reflect a single preferred route option, our cost sensitivity analysis shows that much higher construction costs can be tolerated and still maintain a positive business case.

However, the project design and development require further work before a final decision. At present, the design of the road is very immature and needs to be developed to better understand uncertainties. Further investigations, design and preparatory works are required to determine and detail a single preferred option for the route and better understand construction challenges and opportunities. Once this is agreed, the cost estimates should be updated based on the new information, and procurement processes could be initiated to scope out suppliers. If the updated estimates are considered affordable, an updated business case, including validation of potential investments and benefits, would be expected to precisely confirm the benefit-to-cost ratio. Further, decisions around regional investment strategies, cost sharing, and risk appetite are also required to advance the development towards a final decision. If the updated estimates are considered affordable, an updated business case, including validation of potential investments and revenue benefits, would be required. Further, decisions around regional investment strategies, cost sharing, and risk appetite are also required to advance the project towards a final decision.

The realisation of benefits is embedded within wider considerations and contingent on alignment of interests among key stakeholders, particularly investors, the Government, and air traffic industry. Progression of the project will require strategic dialogue among these key high influence stakeholders. A road map to decision making that all parties can agree to, including accountabilities for elements of a master plan, may prove helpful in structuring this dialogue. But a decision over the next stage of the project is most likely to provide the signal of intent required to foster commitment and dialogue among these stakeholders.

Our combined findings support a decision towards further advancement of the project and starting of the necessary development, investigation, planning and design works to be ready for a final investment decision.

6 Bibliography

[1] C. Dillow, "Russia and China vie to beat the US in the trillion-dollar race to control the Arctic," CNBC News, 6 February 2018. [Online]. Available: https://www.cnbc.com/2018/02/06/russia-and-china-battle-us-in-race-to-control-arctic.html. [Accessed 19 January 2021].

[2] T. Greenhalgh, G. Robert, F. Macfarlane, P. Bate and O. Kyriakidou, "Diffusion of Innovations in Service Organizations: Systematic Review and Recommendations," *The Millbank Quarterly,* vol. 82, no. 4, pp. 581-629, 2004.

[3] NatCen Learning, "The Framework approach to qualitative data analysis," Better Evaluation, http://betterevaluation.org/resources/guides/natcen_framework_approach_QDA, 2012.

[4] A. Villumsen, A. S. Jørgensen, A. Barten, J. Fritt-Rasmussen, L. Løgstrup, N. Brock, N. Hoedeman, R. Gunnarsdóttir, S. Borre and T. Ingeman-Nielsen, "ROAD CONSTRUCTION IN GREENLAND - THE GREENLANDIC CASE," Roadex, https://www.roadex.org/, 2007.

[5] T. Saarenketo, R. Munro and A. Matintupa, "ROADEX BENEFITS AND SAVINGS - ACHIEVING MORE WITH LESS," Roadex, http://www.roadex.org/wp-content/uploads/2014/01/ROADEX-IV-Benefits-and-Savings-2012.pdf, 2012.

[6] A. S. Jørgensen and F. Andreasen, "Mapping of permafrost surface using ground-penetrating radar at Kangerlussuaq Airport, western Greenland," *Cold Regions Science and Technology,* vol. 48, no. 1, pp. 64-72, 2007.

[7] M. Parent, G. Doré;, C. Lemieux; and M. DeGuzman, "Preliminary Investigation for Mechanical Degradation of Permafrost Embankment: Inuvik Tuktoyaktuk Highway Case Study," American Society of Civil Engineers, Reston, Virginia, 2019.

[8] A. M. Melvin, P. Larsen, B. Boehlert, J. E. Neumann,, P. Chinowsky, X. Espinet, J. Martinich,, M. S. Baumann, , L. Rennels, A. Bothner, D. J. Nicolsky and S. S. Marchenko, "Climate change damages to Alaska public infrastructure and the economics of proactive adaptation," *Proceedings of the National Academy of Sciences of the United States of America,* vol. 114, no. 2, pp. E122-E131, 2017.

[9] E. Trochim and T. Schuur, "How is permafrost degradation affecting infrastructure? Arctic Answers:Science briefs from the Study of Environmental Arctic Change," [Online]. Available: https://www.searcharcticscience.org/files/pyramid/assets/aa-018-permafrostdegradationinfrastructure.pdf. [Accessed 19 January 2021].

[10] S. Ormiston and M. Sheldon, "How climate change is thawing the 'glue that holds the northern landscape together'," CBC News, 19 June 2019. [Online]. Available: https://www.cbc.ca/news/canada/north/the-national-permafrost-thaw-inuvik-tuktoyaktuk-1.5179842. [Accessed 19 January 2021].

[11] H. A. Conley, "Arctic Economics in the 21st Century: The Benefits and Costs of Cold," Centre for Strategic International Studies, Washington, DC, 2013.

[12] A. Filipova, "The Effects of Melting Permafrost in Greenland," Pulitzer Center, 12 November 2018. [Online]. Available: https://pulitzercenter.org/projects/effects-melting-permafrost-greenland. [Accessed 19 January 2021].

[13] W. Hughes, "Challenges to arctic construction," AMC Consultants, [Online]. Available: https://amcconsultants.com/experience/challenges-arctic-construction/. [Accessed 19 January 2021].

[14] Global Agenda Council on the Arctic, "Arctic Investment Protocol: Guidelines for Responsible Investment in the Arctic," in *World Economic Forum*, Geneva, 2015.

[15] Roadex Network, "ENVIRONMENTAL ISSUES RELATED TO ROAD MANAGEMENT," Roadex, [Online]. Available: https://www.roadex.org/e-learning/lessons/environmental-considerations-for-low-volume-roads/environmental-issues-related-to-road-management/. [Accessed 19 January 2021].

[16] P. Sherwin, "THE TRILLION-DOLLAR REASON FOR AN ARCTIC INFRASTRUCTURE STANDARD," The Polar Connection, 10 February 2019. [Online]. Available: https://polarconnection.org/arctic-infrastructure-standard/. [Accessed 19 January 2021].

[17] E. Eranti and G. C. Lee, COLD REGION STRUCTURAL ENGINEERING, New York: McGraw-Hill Higher Education, 1986.

[18] D. Cole, "A controversial road project in Alaska could become the next big Arctic battleground between preservation and development," Arctic Today, 25 November 2019. [Online]. Available: https://www.arctictoday.com/a-controversial-road-project-in-alaska-could-become-the-next-big-arctic-battleground-between-preservation-and-development/. [Accessed 19 January 2021].

[19] Government of Northwest Territories, "Inuvik Tuktoyaktuk Highway Project," Public Affairs and Communications, 2017. [Online]. Available: https://www.inf.gov.nt.ca/en/ITH. [Accessed 19 January 2021].

[20] R. Hixson, "Arctic roadbuilding presents icy challenges," Journal of Commerce, 2 February 2016. [Online]. Available: https://canada.constructconnect.com/joc/news/infrastructure/2016/02/arctic-roadbuilding-presents-icy-challenges-1013216w. [Accessed 19 January 2021].

[21] J. Havers and R. Morgan, "Literature survey of cold weather construction practices," Corps of Engineers, U.S. Army, Hanover, New Hampshire, 1972.

[22] D. Lamb and D. Common, "Driving to the top of the world: Exploring Canada's new Arctic highway," CBC News, 19 April 2017. [Online]. Available: https://www.cbc.ca/news/multimedia/driving-to-the-top-of-the-world-exploring-canada-s-new-arctic-highway-1.4073615. [Accessed 19 January 2021].

[23] National Cooperative Highway Research Program, "Effect of weather on highway construction," Transportation Research Board, Washington D.C., 1978.

[24] S. Aho and T. Saarenketo, "MANAGING DRAINAGE ON LOW VOLUME," Roadex III Project, Luleå, 2006.

[25] CBC News, "Remaining Inuvik-Tuk highway to use less gravel to save money," CBC News, 20 January 2016. [Online]. Available: https://www.cbc.ca/news/canada/north/inuvik-tuktoyaktuk-highway-gravel-1.3411200. [Accessed 19 January 2021].

[26] H. Bird, "As Inuvik-Tuktoyaktuk Highway opens, will the $300M price tag be worth it?," CBC News, 13 November 2017. [Online]. Available: https://www.cbc.ca/news/canada/north/inuvik-tuktoyaktuk-nwt-road-worth-it-1.4395052. [Accessed 19 January 2021].

[27] B. N. Porfiriev, D. O. Eliseev and D. A. Streletskiy , "Economic Assessment of Permafrost Degradation Effects on Road Infrastructure Sustainability under Climate Change in the Russian Arctic," *Herald of the Russian Academy of Sciences,* vol. 89, pp. 567-576, 2019.

[28] K. McGwin, "Greenland's first road project connecting settlements clears its last hurdle," Arctic Today, 17 June 2020. [Online]. Available: https://www.arctictoday.com/greenlands-first-road-project-connecting-settlements-clears-its-last-hurdle/. [Accessed 19 January 2021].

[29] J. Pritchard, "INUVIK TO TUKTOYAKTUK HIGHWAY: Wildlife," McGill University, 2014. [Online]. Available: https://inuviktotuktoyaktukhighway.weebly.com/wildlife.html. [Accessed 19 January 2021].

[30] H. Exner-Pirot, "Canada's Northern Economic Development Paradigm and Its Failures," in *Canada's Arctic Agenda: Into the Vortex*, Waterloo, Ontario, Centre for International Governance Innovation, 2019, pp. 15-21.

[31] b. Smith, "Design and Construction of Pavements in Cold regions: State of the Practice," Brigham Young University, https://scholarsarchive.byu.edu/etd/1111/, 2006.

[32] W. Strong, "Inuvik-Tuktoyaktuk Highway open, but with weight restrictions," CNC News, 5 June 2018. [Online]. Available: https://www.cbc.ca/news/canada/north/inuvik-tuk-highway-weight-restriction-1.4693157. [Accessed 19 January 2021].

[33] Government of Northwest Territories, "Mackenzie Valley Highway: Sahtu Community Meetings – February 2020," Government of Northwest Territories, https://www.inf.gov.nt.ca/en/documents-0, 2020.

[34] M. Coppes, "The Inuvik-Tuktoyaktuk Highway will create an all year road for Canadians to access the Arctic Ocean for the first time.," High North Nnews, 15 November 2017. [Online]. Available: https://www.highnorthnews.com/en/canadas-road-arctic-ocean. [Accessed 29 January 2021].

[35] EIRB, "Final report of the Panel for the Substituted Environmental Impact Review of the Hamlet of Tuktoyaktuk, Town of Inuvik and GNWT - Proposal to construct the Inuvik to Tuktoyaktuk Highway," EIRB, North West Territories, 2013.

[36] P. Mason, M. Johnston and D. Twynam, "Mason P, Johnston M & Twynam D (2000) The World Wide Fund for Nature Arctic Tourism Project.," *Journal of Sustainable Tourism,* vol. 8, no. 4, pp. 305-323, 2000.

[37] K. Keil, "Arctic tourism is growing — but that's playing out differently around the region," Arctic Today, 17 February 2017. [Online]. Available: https://www.arctictoday.com/arctic-tourism-is-growing-but-thats-playing-out-differently-around-the-region/. [Accessed 29 January 2021].

[38] C. Ren and D. Chimirri, "Arctic Tourism – More than an Industry?," The Arctic Institute, 3 April 2018. [Online]. Available: https://www.thearcticinstitute.org/arctic-tourism-industry/. [Accessed 29 January 2021].

[39] M. Bystrowska and P. Dolnicki, "THE IMPACT OF ENDOGENOUS FACTORS ON DIVERSIFICATION OF TOURIM SPACE IN THE ARCTIC," *CURRENT ISSUES OF TOURIM RESEARCH,* vol. 2, pp. 36-43, 2015.

[40] Wikipedia, "Nordkapp," Wikipedia, 2021. [Online]. Available: https://en.wikipedia.org/wiki/Nordkapp#cite_note-snl-3. [Accessed 29 January 2021].

[41] C. Runge, R. Daigle and V. Hausner, "Quantifying tourism booms and the increasing footprint in the Arctic with social media data," *Plos One,* vol. 15, no. 1, 2020.

[42] P. Tierney, "Iceland's Arctic Coast Way: Discover hissing geysers, mountains and a beer spa on a road trip along the north-west coast," inews, 17 January 2020. [Online]. Available: https://inews.co.uk/inews-lifestyle/travel/iceland-north-west-coast-arctic-coast-way-reykjavik-geysers-mountains-386619. [Accessed 29 January 2021].

[43] A. Averbuck, "Northern delights: a road trip along Iceland's Arctic Coast Way," Lonely Planet, 15 April 2019. [Online]. Available: https://www.lonelyplanet.com/articles/northern-delights-a-road-trip-along-icelands-arctic-coast-way. [Accessed 29 January 2021].

[44] Arctic Coast Way, "Facts about the Arctic Coast Way," Visit North Iceland, 2021. [Online]. Available: https://www.arcticcoastway.is/en/about/facts. [Accessed 29 January 2021].

[45] A. Duggan, "Stories from the Arctic Coast Way, Iceland's epic new road trip," National Geographic, 27 December 2019. [Online]. Available: https://www.nationalgeographic.co.uk/travel/2019/12/arctic-coast-way-iceland. [Accessed 29 January 2021].

[46] Narvik University College, "ARCTIC REGIONS AND ITS CONCERNS, THREATS AND POTENTIAL CHALLENGES," PREPARATION FOR THREATS TO ENVIRONMENTS IN ARCTIC REGIONS (PRETEAR), https://ec.europa.eu/echo/files/civil_protection/civil/prote/pdfdocs/pretear_final_report_en.pdf, 2010.

[47] J. Olsen, M. Nenasheva and G. Hovelsrud, "'Road of life': changing navigation seasons and the adaptation of island communities in the Russian Arctic," *Polar Geography,* vol. https://doi.org/10.1080/1088937X.2020.1826593, p. DOI: 10.1080/1088937X.2020.1826593, 2020.

[48] RAMBOLL, "Sustianable society development in Arctic cities," RAMBOLL, https://ramboll.com/-/media/images/rgr/lets-talk-megatrends/arctic/report_sustainable-society-development-in-arctic-cities.pdf, 2013.

[49] R. Newcombe, "From client to project stakeholders: a stakeholder mapping approach," *Construction Management and Economics,* vol. 21, no. 8, pp. 1925-1999, 2003.

[50] E. Chinyio and P. Olomolaiye, Construction stakeholder management, Chichester, UK: Wiley-Blackwell, 2010.

[51] L. Christensen, O. Nielsen, J. Rich and M. Knudsen, "Optimizing airport infrastructure for a country: The case of Greenland," *Research in Transportation Economics,* vol. 79, 2020.

[52] RAMBOLL, "FEM SCENARIER VEDRØRENDE FEM SCENARIER VEDRØRENDE," Grønlands Selvstyre Departementet for Boliger og Infrastruktur, Nuuk/Copenhagen, 2018.

[53] Government of Greenland, "tatus på arbejdet om Kangerlussuaqs fremtid," Naalakkersuisut, 20 01 2021. [Online]. Available: https://naalakkersuisut.gl/da/Naalakkersuisut/Nyheder/2021/01/2001_kangerlussuaq. [Accessed 01 March 2021].

[54] The Wilson Center, "Arctic Infrastructure Inventory," The Wilson Center, 2020. [Online]. Available: https://arcticinfrastructure.wilsoncenter.org/. [Accessed 19 January 2021].

[55] C. Burn, "Northern Canada after Climate Equilibrium," in *Canada's Arctic Agenda: into the Vortex*, Waterloo, Ontario, Centre for Intgernational Governance Innovation, 2019, pp. 23-30.

[56] J. Hjort, O. Karjalainen, J. Aalto, S. Westermann, V. E. Romanovsky, F. E. Nelson, B. Etzelmüller and M. Luoto, "Degrading permafrost puts Arctic infrastructure at risk by mid-century," *Nature Communications,* vol. 9, 2018.