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Thank you for the opportunity to provide testimony on the challenges of infrastructure in the Arctic. As an engineering professor at the University of Alaska Fairbanks that specializes in marine civil infrastructure, I have been studying the topic of Arctic Marine Civil Infrastructure, in the context of engineering design and construction, for the past two years. During this time, I've visited communities on the North and Northwestern Alaska coastlines and conversed with many Arctic stakeholders including Federal and State Agencies, oil-and-gas and mining interests as well as residents of communities in the region.

Before I continue, I would like to clarify that by *marine civil infrastructure*, I am referring to civil engineering infrastructure that supports maritime operations.

Infrastructure Challenges for Stakeholders

When I began my work on this topic, I was immediately struck by the overall lack of infrastructure. Existing roadways are generally undeveloped and not connected to the contiguous highway system. There is no rail system. Transportation consists of annual barge service along with air service that is more frequent. Since barge traffic is sporadic during the one or two months of ice free seas, all materials must be carefully scheduled as much as a year in advance. Any missing materials must be either flown in or sent via barge the following year.

I've also come to understand that the lack of infrastructure has precluded development of significant mineral resources in Arctic regions of Alaska.

As far as existing port and harbor facilities: There is a port in Nome, Alaska. This facility has a draft of 25 feet and limited dockage. There is a pier servicing the Red Dog zinc mine, but this facility is specialized for loading ore onto vessels that lighter to larger vessels offshore. An assortment of other facilities servicing barges also exist in the Arctic; along the coasts and in some of the major river systems. These barge facilities are characterized by shallow depth; approximately 10 feet or less.

Presently, the norm for Arctic coastal communities is that existing housing, water, wastewater and power utilities only marginally meet community needs. Consequently, shore side support for escalating maritime activities, as well as development of any new marine infrastructure, will likely overwhelm these communities.

The rigors of the Arctic cannot be overstated. People and facilities in this environ must contend with extreme cold, permanently frozen soil (permafrost) and lack of daylight in winter. In addition, coastal communities and marine infrastructure must contend with intense wind and wave conditions, subsea permafrost, accelerating erosion and potentially catastrophic hazards from sea ice. These harsh conditions will significantly shape development of marine infrastructure in the Arctic as well as stakeholder activities.

Extreme cold impedes the ability of humans to do tasks and can cause equipment to operate at a diminished rate or not at all. There is a point at which productivity is essentially zero and activities must be stopped; primarily due to the inability of emergency responders to operate. During the winter months it should be anticipated that operational and construction activities will be hindered or halted altogether. Because of this, most construction activities will be confined to three or four favorable months in the summer.

Permanently frozen soil extending out into the sea is known to exist but is not well documented or understood. This *subsea permafrost* presents two challenges. First, it may make dredging impractical since frozen soil tends to be more like rock. Secondly, if exposed by dredging, and as climatic warming continues, the permafrost will melt. This will require carefully designed foundation structures which can either keep the permafrost frozen or perform well should the permafrost melt. The presence of subsea permafrost will also affect navigation channel design and construction.

Those who routinely transport freight in the Arctic are keenly aware of intense winds and waves that can occur. Delays caused by adverse winds, waves or ice movement are commonplace. Committee members may be familiar with the popular television show, Deadliest Catch, and can imagine these challenges, and understand how delivery schedules are routinely altered by days or even weeks. Another way to think of this is to contemplate a long route crossing intense weather and rough seas, to a remote location, with no supplies or safe haven along the way. It is easy to see the challenge of planning and logistics for operations or construction in the Arctic.

Eroding coastlines, exacerbated by longer periods of exposure to wave action (a result of diminishing sea ice) will impact marine civil infrastructure in the Arctic. The soil that is washed away from the shore could be described as flowing mud. Water transports this mud which eventually settles on the seafloor. This action can fill dredged navigation channels and the erosion itself can consume shore side infrastructure. The latter has and is occurring in some Arctic coastal communities.

The presence of sea ice is cause for concern and must be handled with care in the design and construction of coastal infrastructure. "Ice out", when the ice finally breaks away from the shores in late spring and summer, is an exciting time for every community along Alaska's northern coastline because it allows fishing and the delivery of supplies. However, just as the ice is moved offshore by the wind, it can be blown back to shore in a matter of hours. When this happens, an ice floe can act like a bulldozer as it is blown towards shore. The ice-mass will impact marine structures with extraordinary force. And, it is not uncommon for these "bulldozers" to ride up on shore for some distance. These facts must be addressed in siting and designing infrastructure along the Arctic coast. The portion of the ice floe beneath the water will gouge the seafloor, excavating soil and forming trenches. This action can destroy subsea pipelines as well as dredged navigation channels. And it must be noted that each year there are thousands of these bulldozers in the shallow waters along the Arctic coast of Alaska. Virtually no portion of the U.S. Arctic coast is unaffected by sea ice.

Creating new infrastructure in the Arctic will be constrained by the fact that researchers know so little about it – from an engineering perspective. Arctic infrastructure challenges are unique and there are few engineers and construction contractors that have considerable experience with them.

In a broader context, *reliably* engineered systems – systems with an acceptably low probability of failure – require adequate knowledge of demands placed on the system. Simply stated, we design engineered systems for the extreme, not the mean. Quantitative information about the extremes of environmental conditions in the Arctic, including waves, wind, currents and, sea-ice conditions, is not readily available. Therefore, information needed to design reliable infrastructure in this region is generally not available.

I would like to be clear, none of these comments are meant to indicate Arctic Marine Infrastructure is impractical. Rather, they are meant to briefly outline some of the challenges we face and information we need to be successful.

Investments in Infrastructure

In the venues I've attended on the Arctic and its challenges, and comments from the various stakeholders, I will summarize sentiments concerning arctic marine infrastructure as follows: "Build it and we'll use it."

In the context of maritime operations, the most limiting factor appears to be the ability to refuel and resupply in the higher latitudes of the Arctic. In light of this, an adequate refuel and resupply point, much further north than Dutch Harbor, would greatly benefit arctic maritime operations for a range of stakeholders. Such a facility could be: a port; a lightering facility – in which fuel and supplies are stored on land and transported to vessels offshore via smaller craft; offshore fuel moorings – a vessel mooring connected to a subsea pipeline conveying fuel from storage tanks onshore (this option could be coupled with lightering for supplies). There are other possibilities beyond what I have stated.

While the port option may be most desirable to some stakeholders, the latter options are potential near term goals that would enhance our ability to operate in the Arctic. Concepts like the lightering facility or the fuel mooring may also be approached as interim measures that will provide some level of service until a port can be built.

In consideration of new economic opportunities in the Arctic, the presence of a port will likely promote diverse economic development. However, a port facility is just that, a "port", a "portal" or "doorway"; a transition between modes of transportation. On one side of the "door" is, of course, marine transportation. An economically driven port will require a companion project on the other side of the door. This is the case for all other economically orientated ports in the Nation. The companion project would likely be rail, roadway or even airport infrastructure.

Another key area of need is basic shore side civil infrastructure. Facilities with adequate lodging, water, wastewater and storage facilities necessary to support significant seasonal or sustained operations by private or government entities are not generally available. In my view, development of shore side civil infrastructure is necessary before any other infrastructure development.

Thinking long term, and in consideration of all stakeholders' needs, it may be beneficial to pursue the question of marine infrastructure needs in terms of an Arctic Marine Transportation System. While a single infrastructure asset will benefit one or more stakeholders, a well-planned system of civil infrastructure assets could potentially be even more beneficial to a wider set of stakeholders. Defining such a system beforehand will surely result in more efficient use of resources than a system pieced together in a discretionary manner.

Thank you

This concludes my written testimony.