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# Rethinking business-as-usual: Mackenzie River freight transport in the context of climate change impacts in northern Canada

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ABSTRACT

The Mackenzie River is a major transportation route serving many remote northern Canadian communities and mining sites. The river is only navigable during the summer and early fall, when clear of ice. However, the river's water conditions have changed significantly in recent years, and are expected to continue to do so, resulting in increased uncertainty for waterway transport. This paper presents a model for providing guidance to shipping companies, customers, and government on how shipping patterns may need to evolve to effectively adapt to changing climate conditions. Future freight volumes are forecasted using time series analysis. Then, logistics cost optimization is used to incorporate predicted water flow profile changes in shipping companies' future delivery schedule planning. Results indicate that future waterway freight delivery capacities in September and October may be insufficient to transport forecasted volumes, and shipping companies may be advised to arrange for increased delivery activities in June and July. If delivery capacities are constrained by equipment and crew availability rather than water conditions in the first half of the shipping season, shipping companies may also need to take advantage of earlier anticipated ice breakup to begin the delivery season earlier. Incorporating this method for climate change adaptation in freight schedule planning may aid both shipping companies and government agencies in rethinking current practices. The method is particularly suitable for a region where harsh environmental conditions, climate change, and extreme remoteness have an overwhelming impact on operations, and logistical delays are considered quite differently from supply chains further south.

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## 1. Introduction

This paper discusses climate change adaptation needs in freight schedule planning on the Mackenzie River in the Northwest Territories (NWT) of Canada, intending to provide guidance to shipping companies, customers, and government on how freight delivery patterns may need to evolve in order to effectively adapt to future climate conditions. Specifically, we incorporate predicted water flow profile changes in shipping companies' future delivery schedule planning. The Mackenzie River is a major transportation route connecting remote northern communities to southern Canada's transportation network (Mariport Group Ltd., 2011). In recent years, water conditions on the Mackenzie River have changed significantly, threaten-

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ing this once highly reliable freight delivery route. According to William Smith, VP Logistics and Business Development at the Northern Transportation Company Limited (NTCL), a major shipping company operating on the Mackenzie River, water levels at the north end of the river from August 2014 to the end of the season were significantly lower than previous years (personal communication, December 4, 2015). Consequently, this severely impacted NTCL's tug-and-barge operations, such that deliveries planned to communities located towards the north end of the river did not occur. To adapt to these changing water conditions, shipping companies must consider changes to their delivery strategies and resulting scheduling. Although planning freight deliveries earlier in the season during good water conditions could improve delivery reliability, there are significant internal and external costs to implement such changes. Therefore, balancing the additional costs involved with planning new schedules against the benefits of taking advantage of better water conditions is necessary for greater efficiency.

In this research, we first forecast future freight volumes using time series modeling. Then, delivery capacities are estimated using historical waterway freight data as well as historical and future stream flow profiles. A logistics cost optimization model is developed to determine alternative marine shipping schedules that better align with predicted water conditions, in particular, factoring in the benefits of taking advantage of high water levels and stream flows. We also conduct a sensitivity analysis of the cost function parameters. Numerical results indicate that companies will need to consider changes to freight deliveries historically made towards the end of the delivery season, in order to decrease the likelihood of non-delivery (such as that experienced in 2014[1]). In particular, companies should consider starting the shipping season a few weeks earlier (and take advantage of earlier ice break-up) and place more equipment and crew during the earlier part of the season. The results can help shipping companies, customers, and government agencies better understand how current shipping practices will require rethinking in order to effectively adapt to climate change impacts. It may provide guidance to shipping companies and their customers on how their delivery schedule planning may be modified to better serve future demands in changing conditions. It may encourage government agencies to help facilitate these new delivery schedules by establishing policies to set up marine navigation aids earlier in the season. It also encourages government to support the development of alternate modes of transport, to guard against economic losses in cases of unexpected waterway delivery failures in late-season months. This method was developed specifically for this northern context where harsh environmental conditions, climate change impacts, and extreme remoteness overwhelmingly impact operations, and logistical delays are considered quite differently from supply chains further south.

## 2. Background

The Mackenzie River is a major freight transport route in the Northwest Territories (NWT), serving communities and mine sites in both the NWT and Nunavut (Fig. 1). The river, which is considered to be ultra-shallow operating conditions, is only navigable when it is clear of ice, from about early June through late-September or early-October. Because of the ultra-shallow conditions, there are several hazard points on the river that are difficult (if not impossible) to pass under low water conditions. Due to the remoteness of this river, there is very little supporting infrastructure; there are no locks, and very few docks. However, the Canadian Coast Guard does install navigational buoys in the spring, after (river ice) break-up, before the start of the summer shipping season.

In 2010, the annual tonnage of freight delivered on the river was estimated to be in the range of 40,000–50,000 tons (PROLOG Canada and EBA Engineering Consultants Ltd., 2010). In addition, due to its the remote northern location and short operating season, there are only several shipping companies that provide freight delivery services on the Mackenzie River. In addition to several very small operators with limited delivery range, there are two major companies operating on the river: Cooper Barging Service Limited (CBSL) and Northern Transportation Company Limited (NTCL) (Transport Canada, 2012). CBSL's river terminal is located in Fort Simpson, while NTCL's is located in Hay River (see Fig. 1). However, NTCL has had the most significant share of freight volumes on this river, with about 3–4 times the annual delivery volumes of CBSL (PROLOG Canada and EBA Engineering Consultants Ltd., 2010), as well as the greatest delivery range.

Freight is transported on the Mackenzie using tugs and barges. Up to six loaded barges are pushed downstream (i.e. north, towards the Beaufort Sea) by a single tug boat. There are three types of barges used by NTCL (Series 800, Series 1000, Series 1500a/1500b), with maximum loading capacity varying from 900 to 2200 tons (Northern Transportation Company Ltd., 2016a, 2016b). NTCL has ample storage capacity at their Hay River terminal, with more than 67 acres of indoor and outdoor space (Northern Transportation Company Ltd., 2016a, 2016b).

In addition to the river, freight is also transported in this region by road and air. The road network consists of all-weather roads and winter roads that are typically operated between mid- to late December and early to mid-April of the following year (Department of Transportation, GNWT, 2016a). The road network is very sparse, and consists largely of winter roads; only one-third of the land area in the Northwest Territories is within 100 km of all-weather roads (Department of Transportation, GNWT, 2011a). The Government of Northwest Territories (GNWT) has been investing in the upgrading and expansion of transportation infrastructures, including in the expansion of the all-weather roadway system, to provide better services for local communities and mining activities (Department of Transportation, GNWT, 2016b). An all-weather

[1] In September and October 2014, water levels on the Mackenzie River near Fort Good Hope dropped to levels significantly lower than previous years, resulting in massive delays and many non-deliveries. This ultimately resulted in large financial losses for the shipping companies.

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