NORTHERN SEA ROUTE VS. SUEZ CANAL ROUTE: EFFECTS OF EMISSION CONTROL MEASURES

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ABSTRACT – Retreat of Arctic Sea ice makes the Northern Sea Route (NSR) an alternative maritime corridor over the Suez Canal Route (SCR), although more NSR voyages generate vessel-based emissions to the fragile Arctic Sea. Thus, emissions-control measures (ECM) are considered for sustainable NSR navigation, although they would harm NSR's feasibility. This study analyzes NSR's feasibility with the effect of speed optimization as an operational ECM, heavy fuel oil (HFO)-banned area and emission tax as regulatory ECMs and an emission trading system (ETS) as a market-based ECM compared to SCR. An optimization model decides vessel speeds and HFO-banned areas for minimizing cost and emissions of voyages. Free-ice, medium-ice, and heavy-ice scenarios are analyzed considering spatial-temporal variation of ice conditions. Several scenarios indicate fewer emissions and costs with NSR than SCR. Ice-breaking requirement, slow steaming potential, and fuel prices significantly influence on NSR's feasibility. Effect of ETS is analyzed considering 174 voyages via NSR over SCR. An optimization model decides optimum route considering marginal abatement cost. Results found 37 and 81 voyages for NSR if SCR's speed equals 10 and 15 knots, respectively. NSR voyages increase at high prices of carbon allowance and results vary based on the free-emissions quota and navigation month.

Keywords: Northern Sea Route; Suez Canal Route; Speed optimization, HFO-banned areas, Emissions trading system

1. INTRODUCTION

The NSR becomes an alternative route in the global shipping market by shortcutting voyages between Asia and Europe, with 40% saving of voyage distance over the SCR. NSR extends between the Atlantic and the Pacific Oceans along the Russian coast of Siberia and the Far East [1]. Although it saves voyage distance- and time ([2], [3]), NSR produces vessel-based emissions to the fragile Arctic Sea, which has a unique biodiversity due to cold temperature [4]. Hence, regional and international bodies propose different ECMs such as speed optimization, emissions tax, and EC areas to minimize adverse impacts from Arctic shipping. Although ECMs derive environmental benefits, they could harm the NSR's economic feasibility by adding additional costs to the vessel operators. Thus, they should be enforced considering economic and environmental perspectives for the sustainable development of Arctic shipping. Since NSR and SCR act as alternative competitive maritime corridors for the East-West trade, this study aims to analyze NSR's feasibility over the SCR with and without ECMs. As the ECMs, this study first considers speed optimization as an operational measure and HFO-banned areas and emission tax as regulatory measures. Speed optimization affects fuel consumption due to the non-linear relationship between vessel speeds and fuel burning. An HFO-banned area is a designated area where vessels are banned from burning HFO. Hence, vessels should switch from HFO to marine gas oil (MGO), a more environmentally friendly fuel [5], inside HFO-banned areas. Besides, a vessel operator should pay an emission tax proportionate to the vessel's emissions, estimated in carbon dioxide equivalent (CO2e). Since NSR's feasibility is analyzed over SCR, two alternative speed scenarios: 10 and 15 knots, are assumed for the SCR. Further, NSR's feasibility is affected by the ice-condition; thus, three ice-condition scenarios: free- (Aug-Sep), medium- (Oct-early Nov), and heavy-ice (late Nov-Dec) are assumed. Thereafter, the effect of an emission trading system (ETS), a market-based ECM is analyzed on NSR's feasibility by estimating potential vessel diversions from SCR to NSR with an optimization model. ETS is an incentive-based instrument to

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reduce emissions from the maritime sector through allocating and auctioning GHG emission allowances. This study significantly contributes to the researchers, practitioners, and policymakers in Arctic shipping by discussing NSR's feasibility from economics and environmental perspectives for a more sustainable NSR navigation.

2. MATERIALS AND METHODS

To discuss NSR's feasibility, the voyage costs and emissions if using NSR and SCR are estimated and compared. As the cost components, capital cost, operating cost, fuel cost, emissions tax, and ice-breaking cost are considered for NSR. In SCR, toll cost of Suez Canal is considered. Besides, premium costs are assumed for NSR navigation compared to an open-water vessel used for SCR. In optimizing NSR speed, numerous navigation legs are considered to incorporate ice conditions variation at navigation time because it influences the vessel's maximum speed. Thus, a spatial-temporal ice-condition distribution map is created with daily ice-thickness and ice-concentration data obtained from the ADS-TOPAZ4 database. Navigation rules such as conditions for navigating at reduced speed, with icebreaker assistance, etc. are decided based on the vessel's ice-breaking capability. Optimum HFO-banned areas are selected from 17 potential areas designed with QGIS and AIS data. The fuel consumption is estimated with ship's engine load, power, weather and fouling correction factors, auxiliary engines, and boilers, among others. Fuel type is decided based on HFO-banned areas because a vessel uses MGO inside these areas instead of HFO. Total emission is estimated with multiple emission types (CO2, CH4, N2O, and BC) and their global warming potentials. A mixed-integer non-linear optimization model decides optimum speeds and locations of HFO-banned areas with two alternative objectives: minimizing total cost (MC) and minimizing total emissions (ME). Forty-eight scenarios are analyzed considering NSR's status quo, NSR's optimization with MC and ME objectives under three ice conditions, and SCR navigation with under 10 and 15 knots speeds. To analyze the effect of ETS, 174 voyages that demonstrated distance-saving by NSR over SCR are selected and optimal route (NSR or SCR) is decided to reduce the combined cost of all voyages. To understand the ETS implications, three scenarios are analyzed based on free emission quota decided as: 1). Least emissions, 2). Highest emissions and 3). Average emissions produced by two routing options. Considering selected 174 voyages with specific origin-destinations, 522 analysis are done considering NSR navigation and SCR navigation with 10 and 15 knots speeds.

3. RESULTS AND DISCUSSION

As the main findings, at the status quo, all voyages incur higher costs at medium and heavy ice than free ice conditions due to the ice-enforced cost. The lowest emissions are observed at medium ice conditions due to its slower speed. If considering NSR's feasibility with ECMs, speed optimization encourages slow steaming via NSR than its status quo while increasing voyages duration over 15 knots speed via SCR. NSR is more environmentally friendly with ECMs than its status quo, with 20–50% CO2e savings. Although NSR's navigation without ECMs can be feasible over 15 knots speed via SCR, it is not feasible over SCR's 10 knots speed. Although the ME objective derives slower speeds to support fuel-saving, it increases NSR's voyage costs by having higher capital and operating costs caused by longer voyage durations. Thus, focusing only on the environmental objective is not recommended. Since the MC objective reduces NSR's cost over SCR despite the ice conditions, especially if emissions tax is enforced on both routes, a speed limit equals to the optimum speed can be enforced to the NSR. However, enforcing an emission tax only for NSR would harm NSR's feasibility if no emissions tax is enforced to the SCR. Despite the positive or negative cost savings, NSR with ECMs significantly reduces environmental emissions, as highlighted by over 70% CO2e saving in some scenarios. The selected HFO-banned areas vary spatially based on ice conditions scenarios. In some scenarios, slower speed incurs higher costs due to increased operating and capital costs with lengthier voyage durations that cannot compensate for the decrease in fuel cost. Additionally, this study analyzes the sensitivity of fuel prices and maximum acceptable voyage duration on NSR's feasibility. Accordingly, a trend of reducing emissions is observed when increasing fuel prices due to extreme levels of slow steaming. However, NSR's cost increases at higher fuel prices because the effect of high fuel prices, higher capital, and operating cost

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exceeds the benefits of reducing fuel consumption and emission tax at a slower speed. Besides, extreme slow steaming by voyages via NSR is not recommended because it increases voyage costs despite the reduction in emissions.

Considering the effect of ETS, many voyages indicate negative cost-saving and emission-saving with NSR at the status quo without ETS especially when SCR's speed equals to 10 knots. When considering the navigation months, cost and emission savings by NSR are mostly highlighted between September – October months because of more favorable ice conditions for vessel navigation via NSR. When deciding feasible vessel diversions to the NSR with the effect of ETS, this study assumes that if the marginal abatement cost of emissions is lower than the market price of carbon allowance, there is a potential to make an economically feasible diversion to the NSR. Accordingly, when SCR's speed equals to 15 knots, the number of feasible diversions to NSR is increased from 89 to 138 voyages when the market price of carbon allowance increased from 10 to 150 USD/MTCO2e. Thus, NSR's feasibility is enhanced with the effect of ETS. However, only a limited number of feasible diversions can be seen even at a high price of carbon allowance if the SCR's speed equals to 10 knots. Hence, with the slow steaming strategy with SCR, ETS would not significantly increase the NSR's attractiveness. Next, considering the results of optimization model with ETS, 96 voyages are diverted to the NSR. Moreover, all voyages in August and September are diverted to the NSR due to the potential cost saving with NSR during these months. Compared to the status quo without ETS, the implementation of market based ECMs such as ETS helps to enhance the attractiveness of NSR to the vessel operator.

4. CONCLUSION

The study analyzes NSR's feasibility over SCR with the effect of speed optimization, HFO-banned areas, emission tax, and ETS as operational, regulatory, and market-based ECMs. Results highlight NSR's feasibility especially when emission tax is enforced on both NSR and SCR. However, since economic and environmental objectives demonstrate a trade-off relationship, these ECMs should be decided considering both environmental and economic perspectives simultaneously for a more sustainable Arctic navigation considering the concerns of all stakeholders including cargo owners. Also, results indicate a higher number of feasible diversions of voyages to the NSR with the effect of ETS, indicating the benefit of such market based ECMs to encourage more sustainable operations in the maritime industry. Although this study analyzes NSR's feasibility only from economic and environmental perspectives, NSR navigation imposes serious risks, challenges, and geopolitical concerns that can be discussed in future studies. Besides, more accurate cost estimation methods can be considered in future studies.

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