**Simulation Modeling of Marine Transport Systems Operating in Ice Conditions**

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**ABSTRACT**

Evaluation and optimization of the parameters of marine transport systems, which operate in polar regions, is an important research field nowadays. Especially it’s important in case of oil and gas transportation. Current practice shows that configuration of the transport system (the number and characteristics of gas carriers or oil tankers, capacity of shore storage etc.) should be determined in the early stages of field development.

Simulation modeling of marine transport systems is an effective method to optimize configuration and characteristics of the transport system in the early stages of field development. This paper is devoted to simulation of marine transport systems, including examples of modeling of LNG transportation from the field in the Barents Sea at various distances using specially developed simulation model. Particular attention is paid to the influence of ice conditions severity on different economic indicators. The article also contains a comparison between traditionally used mathematical programming methods and simulation modeling approach in the context of unstable ice conditions and requirement of regular shipment.

**KEY WORDS:** Simulation modeling, optimization, marine transportation, arctic

**NOMENCLATURE**

- LNG — Liquified Natural Gas;
- MTS — Marine Transport System;
- MP – Mathematical programming;
- SM – Simulation modeling.

**INTRODUCTION**

Transport systems associated with the marine transportation of hydrocarbons fulfil an important function in the modern economy and will play the same role in the future. At the same time, global oil and gas projects inevitably shifts to the north, in the shelf zone of the Arctic Ocean. Resources of the largest Russian fields, such as Shtokman, Rusanovskoye, Prirazlomnoye, Dolginskoye and others, are expected about 10 billion tons of oil equivalents (o.e.). The largest field in arctic offshore is Shtokman field, and it is expected about 3.9 trillion cub.m. of gas and 56 million tons of gas condensate. Despite that difficult climatic conditions and technological and economic problems put off start of the Arctic field development, their economic potential is very important.

Arctic offshore development includes an investigation of many important particular issues, and one of them is a marine transportation in ice conditions. One of the most important challenges in this field is an optimization of marine transport system (MTS) configuration (i.e. the number and characteristics of gas carriers or oil tankers, capacity of shore storage etc.) that ensures oil and gas deliveries strictly in time schedule with the smallest transportation expenses.

Arctic transport vessels are usually built for certain MTS and corresponding errors in evaluation of their characteristics can revert back in the future. This is due to the fact that the freight market of ice class tankers and gas carriers practically does not exist, so faults in estimation of quantity and tonnage of such vessels could not be covered by freight market. Furthermore ice class ships lose out in propulsion efficiency and fuel consumption to usual ships and thus they have no possibility to work effectively at freight market. Therefore, the configuration and characteristics of the marine transport system, operating in Arctic conditions, require especially careful investigation and optimization.

Such optimization of marine transport systems is a long-studied problem and there are two basic approaches most often used to solve optimization problems:

- Mathematical programming,
- Simulation modeling.

**MATHEMATICAL PROGRAMMING**

Mathematical programming (MP) is discipline that concerns the optimum allocation of limited resources among competing activities, under a set of constraints imposed by the nature of the problem being studied. These constraints could reflect economic, technological, marketing, organizational and many other considerations. In broad terms, MP can be defined as a mathematical presentation aimed at finding the best possible allocation of scarce resources.

**Formulation of the optimization problem in MP.**

General form of an optimization problem in mathematical programming is as follows: