Nord Stream Project - Pipeline Safety Against Ship Traffic Related Threats:
Quantitative Risk Assessment Approach

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ABSTRACT
The two 48” Nord Stream pipelines run almost parallel along the Baltic Sea for an offshore length of approximately 1220 km each, crossing waters of five European countries: Russia, Finland, Sweden, Denmark and Germany. The Baltic Sea is one of the most congested shipping areas in the world. An average amount of 2000 ships of considerable size is contemporaneously involved in offshore operations, and up to 5000 ships cross the Baltic Sea every month. The ship traffic includes large oil tankers, ships carrying dangerous and potentially polluting cargoes and many large passenger ferries.

The interaction of the Nord Stream pipelines with the commercial ship traffic has been carefully assessed and pipeline protection measures have been carefully designed. In particular, the Nord Stream pipelines safety against ship traffic related threats - dropped objects, dropped and dragged anchors, sinking ships and, where relevant, under keel clearance and grounding - was analysed in detail by means of Quantitative Risk Assessment (QRA) methodology.

This paper discusses the applied QRA methodology and the project results.

KEY WORDS
Pipeline safety; ship traffic; hazardous scenario; quantitative risk assessment.

INTRODUCTION
The two 48” Nord Stream pipelines (Fig. 1) run almost parallel along the Baltic Sea, which is one of the most congested shipping areas in the world. The pipeline interaction with commercial ship traffic may represent a threat for offshore pipelines, as it influences the pipeline routing and decision about pipeline protection measures (trenching or cover).

A wide bibliography is available concerning ship traffic analysis and accidental scenarios, studies on the interaction mechanisms and design application, to define the minimum measures which could ensure an acceptable level of pipeline safety during its operational life. Colquhoun (1985) has provided a synthesis of the studies carried out in the early 80’s for the Danish Great Belt Gas Transmission Crossing Project, which was considered to be the most complete experience on the risk of ship interference with submarine pipelines. The interest on this subject has increased following De la Mare and Andersen (1980) studies, which gave a synthesis of pipeline failure history, indicating a significant contribution of the anchor damage to failure statistics and stressing the importance for an assessment of the pipeline safety. Hvam (1990) has provided a structured approach to analyze the interaction frequency and the damage consequences for a large diameter pipeline due to dropped and dragged anchors scenarios. This analysis methodology has been used in the quantification of protection measures against commercial ship traffic threats for recent large diameter gas trunklines contracted in the North Sea.

As regards acceptance criteria against commercial ship traffic threats, the following can be said:

• First tentative target failure probability for accidental events set-up by Dutch authority (1987) as $10^{-6}$ per km and per year (actually referred to minor loss of liquid hydrocarbon).