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Investigation of Potential Risk Factors for Groundings of Commercial Vessels in U.S. Ports

Hauke L. Kite-Powell and Di Jin
Marine Policy Center, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, USA

Johan Jebsen, Vassilis Papakonstantinou and Nicholas Patrikalakis*
Ocean Engineering Department, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA

ABSTRACT

We formulate a Bayesian model to estimate the physical risk of grounding during transits into and out of port as a function of potential risk factors. We assemble and analyze information on factors surrounding groundings in three U.S. ports between 1981 and 1995. Although the data are far from perfect, it is possible to establish associations between grounding risk and changes in factors such as vessel type and size, wind speed, and visibility.

INTRODUCTION

Groundings of commercial ships account for about one-third of all commercial maritime accidents, including some of the most expensive in United States history, such as the Exxon Valdez. Like other kinds of casualties, groundings represent a risk because they expose vessel owners and operators, as well as the public, to the possibility of losses. These include vessel and cargo damage or loss, injuries and loss of life, environmental damage and obstruction of the waterway, among others. Strictly speaking, the risk associated with groundings is a product of the probability of the vessel touching bottom and the probability, given that the vessel has grounded, of economic losses (where economic is broadly defined). This paper deals only with the physical risk component of grounding risk. We will show that while the historical data on circumstances surrounding groundings in U.S. waters are neither perfect nor complete, they contain information useful to improving our understanding of why groundings may occur. For a more detailed description of this research, see Kite-Powell et al. (1996) and Jebsen and Papakonstantinou (1997).

Note that we are investigating the association between the circumstances surrounding a transit and the occurrence of groundings, based on historical data. We emphasize the word association as distinct from cause. There is no intent in the present work to prove causal relationships between factors and groundings. Such proof is difficult to accomplish without conducting exhaustive controlled experiments; the data required exceed those available in the historical record. The present research aims only to establish associations, to identify and investigate factors that, on the basis of association and by rational consideration, appear to contribute meaningfully to risk. This approach has the advantage of permitting the inclusion of a range of potential contributing factors. Other methods, such as fault tree analysis (see Amrozowicz, 1996), provide a more detailed view of how groundings are caused but require a great deal of data beyond what is available in the historical record.

*ISOPE Member.
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MODEL

The general hypothesis behind the physical risk model is that the probability of grounding on a particular transit depends on a set of risk factors or explanatory variables. Formally, the model can be described as follows: Let G denote the event that a transit results in a grounding, and let $X = (X_1, X_2, X_3, ..., X_p)$ be the vector of explanatory variables. These variables may be categorical (including binary) or continuous. The model attempts to estimate the conditional probability of G given a specified value x of X. By Bayes' Theorem, this probability is given by:

$$p(G|x) = l(x|G)\, p \,/\, (l(x|G)\, p + l(x|S)\, (1-p))$$

where p is the unconditional probability of G and where $l(x|G)$ and $l(x|S)$ are the likelihoods of x given G and S, respectively. S denotes the event that the transit is completed safely.

To implement this approach, it is necessary to select a set of explanatory variables that discriminates between G and S (Hand, 1981) and to estimate the unconditional grounding probability p and the likelihoods $l(x|G)$ and $l(x|S)$. The vector of explanatory variables X must capture the attributes of the transit that can be expected reasonably to contribute to the likelihood of a grounding. These attributes might include:

• vessel characteristics (draft, beam, maneuverability)

• topography of the waterway (water depth, channel width, channel length, complexity of turns, traffic density)

• environmental conditions (wind, visibility, currents, waves)

• operators (experience with the vessel, training, local knowledge)

• information available to operators (quality of charts, quality of information about tide levels and currents, VTS guidance, navigation aids)

For each attribute, explanatory variables (x_i) must be extracted from historical data as numerical or categorical indicators.

DATA

We initially examined five U.S. port areas: San Francisco Bay, Houston/Galveston, Tampa Bay, Port of New York/New Jersey, and Boston Harbor. For three of these — New York/New Jersey,