A risk-based game model for rational inspections in port state control

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ABSTRACT

This paper analyses the game relationship between port authorities and ship owners under the new inspection regime (NIR). Based on 49328 inspection reports from Paris Memorandum of Understanding (MoU) (2015-2017), we present a Bayesian Network (BN) model to determine vessel detention rates after adding company performance as a new indicator in PSC inspection. A strategic game model is formulated by incorporating the BN model outcomes. The optimal inspection rate from the game model can help improve port authority performance in PSC. An empirical study is conducted to illustrate the insights of the results and provide suggestions for port authorities.

1. Introduction

Traditional flag state control has its limits in terms of ensuring the implementation of maritime safety regulations by ship owners, particularly those choosing open registration. Therefore, Port State Control (PSC), which renders port authorities the ability to inspect foreign vessels in their own ports, is set up in order to avoid the entries of sub-standard ships into their waters and the occurrence of maritime accidents. Since established in 1982, PSC is gradually viewed as the last safety line of defending sub-standard vessels and improving maritime safety because it effectively reduces the appearance of the vessels not fully following the relevant maritime safety regulations. Nevertheless, it is not perfect, leaving the gaps to be addressed and new solutions to be found. According to the PSC inspection records, every year there are still a large number of vessels that do not comply the regulations reckoned by port authorities and fail to pass their inspections, indicating the deficiencies of the PSC system in terms of motivating ship owners to improve vessel quality. Because of the high maintenance cost, some ship owners do not tackle the safety loopholes of their vessels in time. Although facing possible high punishment when his vessel is detained, a ship owner still gambles and takes the risk, mainly because two reasons: first, it is impossible for port authorities to inspect all the vessels entering their ports; second, the ship owner thinks the costs of operating a standard vessel outweigh the risk of being detained by port authorities. From the perspective of port authorities, on one hand, excessive PSC inspections may harm the competitiveness of the ports and increase the burden of ship owners, leading ship owners to turn to other destinations that may have a more relaxed inspection policy (Li et al., 2014a, 2014b); on the other hand, a loose inspection policy is not helpful to stimulate ship owners to implement high intensive maintenance effort, which in return attracts sub-standard ships and possibly causes the occurrence of accidents and consequently economic loss and damage to reputation. Therefore, striking a PSC inspection balance between port authorities and ship owners requires a scientific

decision for rational policymaking. While the port authorities aim at motivating ship owners to maintain their vessels at a high safety level to mitigate maritime accidents, ship owners care more about minimization of the associated costs. Such conflict of interests thereupon forms the game relationship between the two stakeholders.

To improve the PSC inspection system, the much-anticipated New Inspection Regime (NIR) was launched in 2011. According to Paris MoU Annual Report (2011), it is viewed as the most significant change that transforms and modernizes the PSC system in recent decades. Under the new inspection system, the vessel visiting a port will be attributed a ship risk profile through an associated information system, which determines the priority of ship inspections, the intervals between the inspections of a ship and the scope of the inspections. Based on the feedback, the port authority will decide the details of the inspections (i.e. inspection types, detention results, and detention periods). The Paris MoU hoped that the implementation of NIR could efficiently improve the performance of PSC inspection system.

It is noteworthy that an important element that helps to categorize the ship risk profiles in NIR is the performance of International Shipping Management (ISM) companies. Before the implementation of NIR, ISM companies are just third-party managers who, for a negotiated fee and with no shareholding ties with their clients, undertake the responsibility of managing vessels in which they have no financial stake (Mitroussi, 2003). They accepted ships from and managed them on behalf of ship owners without much concern on their technical soundness given that they had no responsibility on vessels' failures of passing PSC inspections. However, this practice has been changed since the NIR was introduced in 2009 and implemented in 2011 on Paris MoU. Paris MoU establishes a shipping company (including ISM) performance formula that takes into account detention and deficiency records of the vessels under the company's management over a period of 36 months. Based on the deficiency and detention rates, the performance of ISM companies is classified into groups of four grades: high, medium, low and very low. A list of 'ISM managers' of poor performance has been developed, consisting of the ISM companies who have shown an unwillingness or inability to comply with the international conventions on maritime safety and/or on the protection of marine environment. Once a vessel is detained, the reputation of its associated ISM will be affected, leading to an increase frequency of inspections in future.

To ensure their profits and maintain their reputation, ISM companies are putting much effort to make them adaptive to the NIR and improving their management level. Considering the vessel quality, ISM companies raise their vessel acceptance criteria to ensure the successful inspection results that the ships under their management can receive. The involvement of ISM companies obviously influences the game between port authorities and ship owners in today's PSC practice.

For port authorities, when regulating their policies under NIR, it is of vital importance to take the company performance into account. However, in this research, as we only focus on the period in which the vessel is already at the port, ISM companies are considered as a factor influencing the decision-making of port authorities, because the selection and determination of ISM companies by ship owners happen before the occurrence of the inspections. Therefore, quantifying the influence of company performance on inspection results becomes the major issue when analysing the PSC inspection game under NIR in this research. Further research may consider ISM companies as a player in the inspection game if the time range of the game is widened.

This study aims at developing a risk-based game model based on Bayesian network (BN) to determine the optimal inspection strategy of a port authority under different circumstances after the implementation of NIR. Based on 49328 primary historical inspection reports obtained from the Paris MoU database in 2015–2017, those related to bulk carriers (i.e. 10,000 records) are selected to build a BN risk model. The BN risk model provides a novel way to obtain the detention rates relating to different company performance levels and vessel quality. They can be used as important input in the subsequent game model construction. Through calculating every payoff during an inspection, a payoff matrix is utilized to present the new BN risk-based PSC game model.

The main contributions of this paper include: (1) to the authors' best knowledge, since NIR went into effect in 2011, company performance is, for the first time, viewed as an important factor influencing the decisions of port authorities in PSC inspection practice and scientific research; (2) BN and game theory are innovatively incorporated to exploit a rational way to precisely quantify the relationship between the port authority and ship owner during an inspection process; (3) it is the first attempt and presentation of a non-cooperative strategic game between port authorities and ship owners after the implementation of NIR. An optimal inspection policy for port authorities is derived from a Nash equilibrium solution; (4) New managerial insights about the optimal inspection rate (policy) are obtained. For instance, with the increase of punishment severity, the optimal inspection rates present a decreasing trend regardless the vessel condition. The declining speed of the optimal inspection rates slows down with the increase of punishment severity; (5) the proposed optimal inspection policy is able to provide real-time PSC decisions for port authorities in dynamic situations accordingly, where the risks constantly change; (6) suggestions are proposed to help port authorities of different economic constrains to make rational decisions. For instance, when a port authority has limited economic constrains, it should choose the optimal inspection rate as suggested by the game model; otherwise it can increase the punishment to an appropriate level as suggested by the model, to tackle the sub-standard effort and illegal actions of ship owners.

The remainder of this paper is organized as follows. Section 2 reviews the current literature focusing on the risk analysis relating to PSC inspections and presents the state of the art of game applications in maritime safety research. Section 3 describes the process of developing a theoretical framework for an optimal inspection policy based on the combination of BN and the game theory. It is followed by an empirical study, result analysis and implications in Section 4. Finally, Section 5 concludes this study with reference to its scientific and practical contributions, limitations and future research directions.