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Influence of external conditions and vessel encounters on vessel behavior in ports and waterways using Automatic Identification System data

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ABSTRACT

The impact of many external factors, such as wind, visibility and current, on the behavior of vessels in ports and waterways has not been investigated systematically in existing maritime traffic models. In order to fill the current knowledge gap and provide a basis for developing a new model to effectively simulate maritime traffic, the influences of wind, visibility and current as well as vessel encounters on vessel behavior (vessel speed, course and relative distance to starboard bank) have been investigated in this study by analyzing Automatic Identification System data collected from the port of Rotterdam. It is found that wind, visibility, current and encounters have significant impact on the vessel speed and relative distance to starboard bank, while vessel course is mainly affected by current and encounters. The results also showed that the vessels would adapt their speed, course and relative distance to starboard bank during encounters. These findings showed the importance of considering external factors and encounters in simulating vessel behavior in restricted waterways and provide a starting point for building up more comprehensive maritime traffic models.

1. Introduction

As one of the important modes of international freight transportation, the scale of maritime transportation has been expanding sharply in recent decades. The increase of both vessel number and size draws more and more concerns for the balance between safety and capacity of maritime traffic: when measures are taken to increase capacity, usually the safety decreases, and vice versa. This holds even stronger for ports and inland waterways, where vessel encounters and external conditions can significantly influence vessel behavior, such as vessel speed and course. In those areas, vessel collisions and groundings occur more often because of the confined space (Darbra and Casal, 2004). As maritime traffic accidents may have serious consequences, such as personnel and property losses, traffic congestion and environmental impacts both in the water and in the surrounding area, it is desirable to properly address the safety and capacity of the maritime traffic system in restricted waterways.

Currently, various simulation models are available to investigate the maritime traffic system. Some of these models have been developed to assess risk of collisions and groundings (Montewka et al., 2010; Goerlandt and Kujala, 2011; Qu et al., 2011), while other models have been built to investigate the effect of vessel hydrodynamics and vessel maneuverability (Sutulo et al., 2002; Sariöz and Narli, 2003). However, most models focus on maritime traffic in open seas while only few investigate the traffic in ports and waterways (Xiao, 2014). And all these models consider only a limited number of external factors.

Initial studies qualitatively showed that the wind and current can effect vessel speed and course in ports (De Boer, 2010). However, the influence of external factors, either wind or current, on vessel behavior was investigated without eliminating the impact of other factors on vessel behavior in this study and the influence of external factors on vessel behavior has not been quantified. A recent maritime traffic simulation study showed that vessel characteristics (type and size) can also significantly influence the vessel behavior in ports (Xiao et al., 2015). Notwithstanding these studies, the influence of external conditions (including wind, visibility and current) and vessel encounters on vessel behavior is not yet fully understood and quantified.

The aim of this paper is to systematically investigate and quantify the influence of external conditions and vessel encounters on vessel speed, course and vessel path in ports and waterways. For vessels sailing in the confined waterways of the port, the vessel path is described by the relative distance to the starboard bank (the distance to starboard bank divided by waterway width). So, vessel speed, course and relative distance to starboard bank are three parameters considered in this paper. As currently no other research specifically focuses on this aspect, the results of this paper are seen as an essential basis for

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improvement of maritime traffic models and investigations on maritime traffic. In addition, this research also shows a method how to utilize Automatic Identification System (AIS) data and cross sections to extract useful information, such as vessel encounters.

Based on this aim, the following research questions were proposed:

Research question 1: How does wind influence vessel behavior (vessel speed, vessel course and relative distance to starboard bank)?
Research question 2: How does visibility influence vessel behavior (vessel speed, course and relative distance to starboard bank)?
Research question 3: How does current influence vessel behavior (vessel speed, course and relative distance to starboard bank)?
Research question 4: How do vessel encounters (head-on and overtaking) influence vessel behavior (vessel speed, course and relative distance to starboard bank)?

In this paper, the research data and approach are introduced in Section 2. Then, the influences of wind, visibility, current and vessel encounters on vessel behavior are presented, respectively, in Sections 3–6. Finally, this paper ends with conclusion and discussions in Section 7.

2. Research area, data and approach

In this section, the research area is introduced, followed by the introduction of the research data and research approach. Then, the statistical analysis method used in this paper is described.

2.1. Research area

The research area used in this study is the Botlek area in the port of Rotterdam, as shown in Fig. 1. This area is chosen because of its high traffic density and the availability of historical data of wind, visibility and current from measuring stations located in this area. The research area comprises three navigation channels: "Nieuwe Waterweg", "Nieuwe Maas" and "Oude Maas". As the main waterways connecting the older port basins with the Sea, the "Nieuwe Maas" and the "Nieuwe Waterweg" have a width of around 400 m and a minimum depth of 13.8 m below Mean Lower Low Water (MLLW), which is the average height of the lowest tide recorded at a tide station in the port area. The vessel traffic in these two waterways mainly consists of commercial vessels including container vessels (59.6%) and General Dry Cargo (GDC) vessels (29.3%). 75% of these are small vessels less than 10,000 gross tonnage (GT). The "Oude Maas" joins the "Nieuwe Maas" from the south and forms the main connection for vessel traffic from the port of Rotterdam to the hinterland. The "Oude Maas" has a width of around 200 m and a minimum depth of 9.6 m MLLW. This condition in the "Oude Maas" restricts vessels, so 95% of the vessels in the "Oude Maas" are small vessels less than 10,000 GT. Among these vessels, 63.7% are GDC vessels and 26% are tankers. In these analyses, the following four navigation directions are distinguished according to main vessel traffic flows:

- Sea-Nieuwe Maas: vessels sail from Sea to the "Nieuwe Maas"
- Nieuwe Maas-Sea: vessels sail from the "Nieuwe Maas" to the Sea
- Sea-Oude Maas: vessels sail from the Sea to "Oude Maas"
- Oude Maas-Sea: vessels sail from the "Oude Maas" to the Sea

2.2. Research data

The research data consists of two parts. Firstly, the vessel behavior is collected from the AIS data, which are provided by the Maritime Research Institute Netherlands (MARIN), using "ShowRoute". The "ShowRoute" is a dedicated software developed by MARIN used for investigation of AIS data. AIS data have turned out to be a useful tool to investigate maritime traffic (Aarsæther and Moan, 2009; Mou et al., 2010; Hansen et al., 2013; Meng et al., 2014). Secondly, the wind, visibility and current data collected from two measuring stations in the research area are provided by the Port of Rotterdam Authority. In this section, AIS data and cross sections used to collect the AIS data are introduced firstly. Then, the available wind, visibility and current data are described.

2.2.1. AIS data and cross sections

In the 1990s, the International Association of Maritime Aids to Navigation and Lighthouse Authorities (IALA) presented to the International Maritime Organization (IMO) the first proposal for AIS, in which the AIS system is designed to identify other vessels including their positions (Eriksen et al., 2006). The purpose of the AIS system is "to contribute to improved situational awareness for shore-side authorities and ships' officers" (Bailey et al., 2008). The AIS system works on Very High Frequency (VHF), so it is possible to detect other AIS-equipped vessels when the radar detection is confined, such as under influence of strong rain or tall buildings. In the International Convention for the Safety of Life at Sea (SOLAS), IMO made AIS mandatory for vessels of 300 GT and more by 2004, and now it is

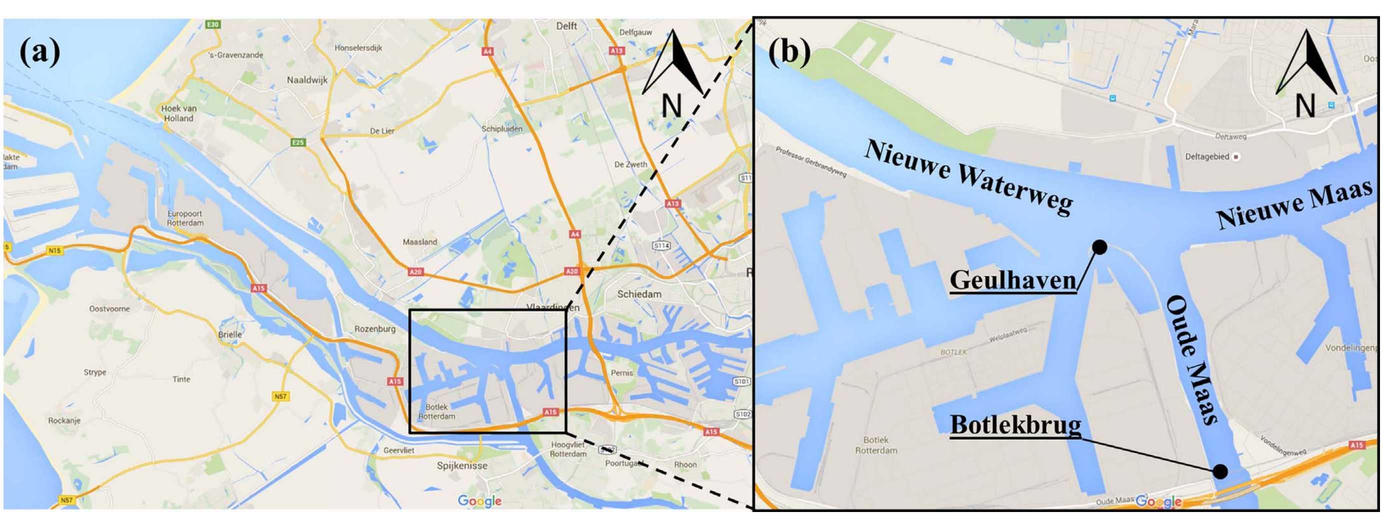

Fig. 1. (a) Location of research area: the Botlek area in the port of Rotterdam; (b) the zoom-in view of the Botlek area, comprising three parts: "Nieuwe Waterweg", "Nieuwe Maas" and "Oude Maas". The locations of the measuring station "Geulhaven" for wind and visibility and the measuring station "Botlekbrug" for current are also specified.