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Simulating the port wet infrastructure: review and assessment

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Abstract

Since the continuous growth of maritime transportation due to containerization, ports play an increasingly important role in the freight transportation chain. In ports, high vessel flows and implicit higher densities increase the relevance of the non-terminal related operations. A few simulation models have been developed in the recent decades with different aims and scopes, but none of them has been assessed based on their ability to represent real vessel traffic in ports. In this paper, we identify the main navigational processes and operations related to the port wet infrastructure and review and assess the current port simulation models. The survey of models presented represents an exhaustive overview of the current state of the art of port simulation models. Their assessment focuses mainly on which processes and operations are covered by each model, both wet infrastructure and navigational behaviour, and it also considers where models are complementary and how accurately they are able to represent real navigation. A set of elements is defined and divided in two parts for the assessment: wet infrastructure representation and navigational behaviour. This review shows that the influence of infrastructure design or vessel encounter on vessel navigation behaviour and free path choice have not been implemented in port simulations. Future port simulation models should cover these relevant elements, among others also explained, for a more realistic traffic performance.

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1. Introduction

Globalization is leading to a rapid growth in maritime transport, both in size and number of vessels. The world seaborne trade has increased substantially in the past two decades (UNCTAD, 2013). Since ports are quite inflexible infrastructures and difficult to expand, the increase in vessel movements has led to more hazardous situations and congestion in some areas. As a result, ports handle a higher traffic demand that implies longer waiting times for vessels and reduces system's efficiency. Because of this increasing demand, navigational related operations inside the port infrastructure, also called 'wet infrastructure', become decisive for port performance. Existing ports need to be optimized or expanded and new ports have to be planned. In both cases, their safety and capacity should be guaranteed and tools to design different scenarios are required.

Maritime transportation simulation models have been proven to be useful tools to represent and predict port operations and processes. Several models have been developed during the last decades with many different purposes. Regarding traffic representation in straits, models consider navigation systems as queueing systems, with first in first out (FIFO) sequences, see for example, Istanbul strait (Köse et al., 2003). Waterway traffic representation in the Osaka Bay was implemented by the Marine Traffic Simulation System (SMARTS) (Hasegawa et al., 2001). This model was also used for marine risk assessment. For a similar purpose, a risk index-based model for vessels was developed, the SAMSON model (Safety Assessment Model for Shipping and Offshore on the North Sea), by MARIN (Maritime Research Institute Netherlands, 2015). Furthermore, a simulation model for vessel traffic based on ship collision probability has been developed (Goerlandt and Kujala, 2011). A more recent vessel traffic simulation tool was implemented to determine the impact of river deepening on navigational issues in the Delaware River (Almaz and Altiok, 2012). Moreover, there are models for detailed port representation and performance analysis, such as Harboursim, a generally applicable model (Groenveld, 1983), or a model developed for the port of Antwerp (Belgium) (Thiers and Gerrit, 1998).

Although a lot of research has been already done in maritime simulation modelling, there is not an existing review of port 'wet infrastructure' simulation models. This paper aims to identify the most relevant processes involved in port navigation performance and to review and assess the models already developed on these processes. The differences in their approaches and drawbacks indicate whether gaps of improvement in the port 'wet infrastructure' traffic simulation modelling research exists.

The outline of this paper is as follows. Section 2 describes vessels real operations in a port. Section 3 identifies the required elements for port 'wet infrastructure' traffic simulation model. Section 4 describes the characteristics of the elements identified. Based on these, the assessment of simulation models will be discussed in two groups, layout and navigational behaviour, in section 5. This paper concludes with a discussion of the comparison results and some remarks for future model development.

2. Port wet infrastructure operations

Ports are complex networks, both from an infrastructure and navigational point of view. This section describes the main operations linked to the wet infrastructure and should lead to a better understanding of them.

Traffic operations in a port start when a vessel arrives and requests access (see Figure 1). The Vessel Traffic Service (VTS) provides information about berth availability and other conditions, such as weather or tide. If it is feasible to enter the port, the traffic situation is checked. Vessels with permission from the quay master can enter the port. Otherwise, they wait outside the port in the anchorage until permission is given. Vessels with specific navigational requirements or limitations will need pilot and/or tug assistance.

Once a vessel is allowed to enter the port, it sails to a specific berth through the approach channel or entrance waterway. Until its arrival at the berthing area, each vessel will sail through different parts of the port, such as turning basins, crossings or inner basins. Each of these parts has specific requirements in sailing and manoeuvring, depending on the vessel characteristics. Vessels can usually sail in any position inside each section of the port, but, to avoid groundings, there are some fixed corridors or paths for vessels with the deepest draughts.

After the vessel has performed all these steps, the berthing process is performed and loading/unloading operations start. These operations aim to control the movement and storage of cargo within the terminal and stacking area, entry/exit gates and rail or road connections. When the loading/unloading operations are completed, vessels are ready to depart; they are required to ask for new permission to leave the port or sail towards another berth. The reverse navigation process occurs when they are allowed to sail towards their exit.