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Operator Function Model to Analyze Ship Accidents Related to Navigation Aids

Seung-Kweon Hong

Department of Industrial & Manegement Engineering, Korea National University of Transportation, 27469, Chungbuk, South Korea

ABSTRACT

A marine Aids of Navigation (AtoN) is a man-made object in waterways used by mariners to determine their ship's location or a safe route. They act like traffic signs on roads used to reduce the risk of traffic accidents. However, traffic signs can't do their job if you can't recognize them, don't understand their meaning, or violate them. In this study, ship accidents caused by the undesirable use of the AtoN were investigated. First, maritime officers' work in the ship bridge work was analyzed using the Operator Function Model (OFM), and among all the tasks derived from the analysis, only the tasks related to the AtoN were selected. Using the selected tasks as a classification system for ship accidents, recent ship accidents in the Korean coast were analyzed. The ship accident analysis was conducted using written verdicts of the Korean Maritime Safety Tribunal. Ship accidents were confirmed in most of the selected tasks. The results of this study can be used for safety education of maritime officers and the deployment, maintenance, and design of AtoN

Keywords: Ship accidents, Aids of navigation, Operator function model, Traffic signs

INTRODUCTION

A maritime navigation aid (AtoN) is any device outside a ship specifically designed to assist a navigator in determining their location or safe route, or to warn of hazards or obstacles to navigation. Navigational aids include buoys, data signs, lights, lighthouses, radio beacons, fog signals, indications, and other devices used to provide indications of underwater information. They act like traffic signs on roads used to reduce the risk of traffic accidents.

Traffic signs play a very important role in conveying operational information to users. Traffic signs are effective only when they are installed in the right places and designed to be easily understood by users (Gholam-ali and Ahmadiyan, 2014). Many studies related to traffic signs on roads have been conducted in various aspects. These studies must have been carried out from various angles, as it can cause traffic accidents if traffic signs are not accurately recognized or incorrectly designed (Ezeibe, et al., 2019, Hussein, 2013). Road traffic sign–related studies includes sign visibility (Kline, et al., 1990), sign luminance (Graham, et al., 1997), sign legibility (Paniati, 1988), sign comprehensibility (Madani, 2000, Al-Madani, and Al-Janahi, 2002), effects of age (Chao, et al., 2013, Dewar, et al., 1994) and drivers' cognitive workload (Lyu et al., 2017).

On the other hand, a representative the AtoN that has been used at sea for a very long time is a lighthouse. Lighthouses were already systematized at least in ancient Egypt. However, despite such a long history, ergonomic research on marine traffic signs is lacking compared to research on road traffic signs. This is probably because the functions of land traffic signs and maritime traffic signs are different. Unlike land traffic signs, modern ships can navigate without the AtoN due to advances in navigation equipment such as ARPA (Automatic Radar Plotting Aid) radar, ECDIS (Electronic Chart Display and Information System) and AIS (Automatic Identification System). The AtoNs have become a means of re-checking navigation routes, hazards, or turning points. Additionally, the AtoNs have limited use, primarily in ports and coastal areas. However, even now, small fishing boats are completely dependent on the aids of navigation. In addition, with the advent of autonomous ships, it is expected to expand the existing functions by supporting autonomous ships (Baek et al., 2019).

This study intends to analyze ship accidents related toAtoN. The users of the AtoN are marine officers who operate the ships. There may be various human errors, such as when the officers do not identify the AtoN, misunderstand one AtoN as another and lack of knowledge about the AtoN. Sometimes AtoNs are misplaced and officers may make mistakes. Mistakes made by the officers with the AtoN can lead to ship accidents. In this study, the work related to the AtoN performed by marine officers on a bridge is analyzed using operator function model (OFM), and it is intended to investigate whether possible human errors lead to actual ship accidents. By analyzing the cases of ship accidents that appeared in written verdicts of the Korean Maritime Safety Tribunal, ship accidents related to the AtoN were investigated.

OPERATOR FUNCTION MODEL FOR MARITIME OFFICERS' TASKS RELATED TO AIDS TO NAVIGATION

The operator function model (OFM) describes the role of an operator in a complex system (Thurman, et al., 1998). OFM provides a framework that can give answers to questions such as "what kind of information do workers need?", "how should the information be combined?", and "when is the information presented?" (Mitchell, et al., 1986). OFM uses discrete math to characterize worker activity as a network of arcuate nodes. Each node represents an operator activity. Arcs connecting nodes represent triggers or transition conditions that initiate, end, or sequence activities (Mitchell, et al., 1986). These triggers can occur outside the system or represent dynamic relationships between activities. State transitions can be non-deterministic, so they can represent operator choice when choosing an activity to pursue. Figure 1 shows the high-level functions of OFM for ship navigation proposed by Lee and Sanquist (2000). In their model, the high-level functions of ship navigation consist of four activities: voyage planning, course execution,

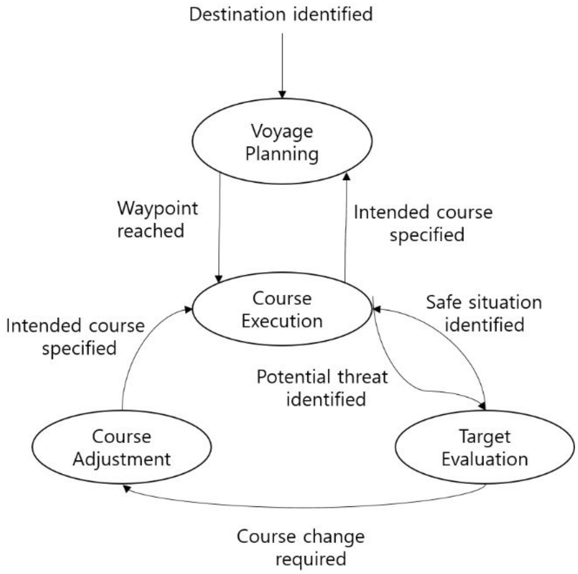

Figure 1: High-level OFM for ship navigation proposed by Lee and Sanquist (2000).

Table 1. Failure modes related to AtoN.

High-level Functions	Related Low-level Functions	Failure Modes related to AtoN
Voyage Planning	Passage Planning	Voyage planning errors because the AtoN cannot be identified or misinterpreted.
Target Evaluation	Identify Target	Target identification error that does not identify the AtoN related to low-depth areas, rocks, and wrecks.
	Interpret the Target	Errors not knowing its meaning or judging it as another AtoN, after identifying the AtoN.
Course Adjustment	Apply Appropriate Rules of the Road	After identifying the AtoN, the error of navigating without properly applying the relevant navigation rules.
Course Execution	Determine Position	Errors in recognizing the AtoN incorrectly when checking the position of one's own ship using the AtoN.

target evaluation, and course adjustment. Each activity at a higher level is in turn made up of several sub-functions.

Lee and Sanquist (2000) proposed an OFM of ship navigation to evaluate the cognitive demands of technological innovations in ship navigation. This study proposes an OFM in order to analyze human errors caused by the incorrect use of the AtoN in ship navigation. Table 1 shows the failure modes related to AtoN derived after analyzing the work performed by Maritime Offiers in the navigation process. Each failure mode has the potential to lead to a ship accident.

SHIP ACCIDENTS REALTED THE AIDS TO NAVIGATION

In order to investigate the cases of ship accidents related to the AtoN, ship accidents that appeared in written verdicts of the Korea Maritime Tribunal for the past 10 years were analyzed. Ship accidents in the written verdicts was about 9.5% of a total of ship accidents that occur in the coast of Korea.

As voyage planning error cases, there were several voyage plans that did not consider the shipwreck and the construction area, and there were also cases where the low depth and reef in the vicinity of AtoN were not properly checked. For an example, the ship accident (Kumho Ferry No. 3) that ran aground at 14:23 on September 23, 2015 occurred due to insufficient information gathering in advance on the rocky area along the route. Instead of the safe southern route of Seorae-Yeo (south direction sign), the relatively dangerous northern route was selected and operated. There was a southern direction sign, so it was necessary to navigate to the south side, where the navigable water area was wide and safe. Northern side had to be avoided as much as possible.

Secondly, there were cases in which it was not possible to identify the AtoN indicating danger due to officers' drunkenness, neglect of vigilance, and interference from surrounding lights. In addition, despite the identification of the navigational signs, errors were found in which they could not properly interpret or understand the meaning. One example is the ship's (Bonchallenger) contact accident that occurred at 00:17 on January 27, 2020. The captain of the ship knew that the construction was going on around the port, and the lights were installed at the construction site, and the captain also recognized the lights during the ship navigation. However, he vaguely recognized the light as the light of a fishing net and did not actively take action to avoid contact accidents.

An example of a ship accident related to course adjustment is the collision between a cargo ship (Hyundai Dangjin) and a towed barge (Jinyang No 5) of a tugboat that occurred on March 14, 2012, around 23:14. This is a ship accident caused by not complying with the traffic rules according to the AtoN. Light buoys were installed sequentially along the recommended route. When navigating close to the recommended route, ships must navigate to the right of the recommended route. However, the cargo ship (Hyundai Dangjin) did not comply with this rule and collided with the towed barge.

Fourthly, the stranded accident of the ship (Taeyoung Sky) which occurred at around 08:35 on July 12, 2010, was an accident that was caused by misjudging the position of the ship by misrecognizing the AtoN. The waypoint on the navigation map was the second lighted buoy, but the first lighted buoy was recognized as the second lighted buoy. After passing the first light buoy on the port side, the bow course was changed to 326 degrees at a position less than 1.6 miles from the point where it should be changed. This leaded to the ship to run aground.

CONCLUSION

AtoN has been used to improve of maritime navigational safety. However, ergonomic research on marine traffic signs is insufficient compared to research on road traffic signs. In this study, the tasks related to the AtoN performed by marine officers on a bridge was analyzed using operator function model (OFM) and ship accidents related to the AtoN were investigated. It was confirmed that all failure modes discovered through OFM lead to actual ship accidents. The OFM presented in this study did not present the low-level functions in detail. A more detailed OFM model is needed in future studies.

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