Implementation of Automatic Identification System(AIS) for Analysis of Marine Traffic Safety

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論文内容の要旨

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専　攻　Maritime Management Sciences

論文題目（外国語の場合は，その和訳を併記すること。）

Implementation of Automatic Identification System (AIS) for Analysis of Marine Traffic Safety

（ＡＩＳデータの海上交通安全性評価への応用に関する研究）

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The Strait of Malacca, considered to be the busiest shipping lane in the world, is located between the east coast of Sumatra Island in Indonesia and the west coast of Peninsular Malaysia, and is linked to the Straits of Singapore at its southeast end. With a length of approximately 500 miles (800 km), the Strait of Malacca is the longest strait in the world used for international navigation. It forms the main seaway connecting the Indian Ocean with the China Sea and provides the shortest route for tankers shuttling between the Middle East and Asian countries.

This research study describes about the application of AIS data for analysis of marine traffic safety. In this case, the Malacca Straits is study area for the analysis. This area classified as a busy area, high traffic density, and high risk area for navigation in the world. Therefore, enhancing safety of navigation is important to be established. The AIS is tool for establish the ship safety navigation. The AIS installation had installed in the Universiti Teknologi Malaysia, Johor, Malaysia by Kobe University, Japan.

Therefore, these research studies consist of 6 chapters. In the chapter 1, the introduction including background, outline, and study area was described. In the Chapter 2, the Automatic Identification System was explored. The explanation about implementation of the AIS to enhance safety of navigation in the marine traffic was described in this chapter. The danger score by considering ship condition, human factors, environmental factors, machinery factors, and navigational factors are established using AHP and AIS, which were described in Chapter 3.

The collision is important issue which has occurred in the Malacca Straits. In this research, as shown in Chapter 4, hazard identification and risk ranking of ship collision were evaluated as step of formal safety assessment. The result is value of risk ranking which has determined using failure mode effect analysis and fuzzy logic method. AIS data is used as source data for make classification of ship's encounter and traffic volume.

In the Chapter 5, the analysis of safety of navigation by considering the traffic density has been analyzed and discussed. In this case, risk assessment is established. Based on AIS data, the scenario of risk assessment have been carried out with different time with actual data. The risk level has been established in head on condition, crossing condition and overtaking condition. scenario taken in the time which have high traffic area, on 2.00h, 10.00h, and 22.00h. The discussion of ship collision probability analysis and consequence analysis are explored in this Chapter. As the results, following conclusions of this chapter have been obtained.

In the Chapter 6, the marine traffic safety based on AIS data has been discussed based on the explanation in Chapter 2 through 5. In the Chapter 6, conclusions of this study are summarized.

Moreover, the results discussed in the chapter 3 are published in the reference [1] and [4],

chapter 4 is published in the reference [1] and [5] and chapter 5 are published in the reference [2], [3] and [5].

According to the IMO, in 2002, AIS information includes static, dynamic, and voyage-related elements. Static information is programmed into the unit at the time of commissioning. Dynamic information is derived from interfaces with a ship's GPS and other sensors. Voyage-related data are entered manually by the ship's captain using a password-protected routine.

The analysis of marine traffic safety in the Malacca Straits had been established. The evaluation of dangerous area, the evaluation of the risk collision and the safety of navigation assessment had been carried out.

The implementation of AIS for evaluate marine traffic safety in the Malacca Straits had been carried out. The AIS is implemented as a source of data that describes the characteristics of ships' traffic volume determined using a geographic information system (GIS). AHP is therefore used for evaluating the safety level in the Strait of Malacca. In this case, weighting factors are determined using AHP. The evaluation criteria are divided into five: Ship condition, human factor, environmental factor, machinery factor and navigational factor. Each criterion divides into sub-criteria and sub-sub-criteria. By combining AHP method and AIS, the simulation and calculation results of the danger score are presented.

The risk evaluation of ship's collision in the Malacca Straits had been established. The evaluations of risk and hazard identification are useful to enhance the safety. In this Chapter, ten scenarios established. The investigation of sea traffic using AIS data and GIS in the Malacca Straits is carried out. The proposed FMEA-Fuzzy method for the evaluation of ship collision risk is described. Finally, The risk ranking results are explored.

The assessment of safety navigation using AIS data had been carried out. In this chapter, the traffic density and probability assessment is calculated based on AIS data. Consequences analysis had been determined. In this Chapter, scenario of risk matrix established based on actual condition using AIS data with different time and different encounter situation. The head on situation, crossing situation and overtaking situation had been analyzed.

Using the AHP, several factors that contribute to accidents in the Strait of Malacca were revealed. In the Strait of Malacca, from 1975 to 1995, a total of 496 casualties were recorded.These involved collisions, contacts, founderings, standings, fire, engine troubles, bilgings and leakages. 35 of the 111 collision cases have caused foundering of the ships, led to fire and explosion or leakages leading to wrecks.

An analysis of several factors that contribute to accidents in the Strait of Malacca indicates the following. First: Ship condition. In the ship condition, the following items are considered: type of ship, length of ship, speed of ship and state of loading. In the actual accident based on type of ship, General cargo ships are at the top the list at 53.15%, followed by tankers at 20.59%, bulk carriers at 6.72%, fishing craft at 4.41%, container ships at 2.94% and liquefied gas carriers at 1.68%. . Secondly, the human element is the most important factor. Several accidents occurred caused by human error. In this case, experience and knowledge, fatigue, overwork, communication are factors that are important for navigators.Thirdly,the environmental factorswill be discussed. In fact, serious accidents have occurred in high traffic density areas. Current, speed other ships, length of other ships, distance between vessels, wind effect, characteristics of area are factors that have contributed to the accidents in the Strait of Malacca. Further on, the machinery factors are described. The high percentage of leaking ships and ships limping with machinery problems must be viewed with deep concern because such casualties can easily develop into or cause catastrophic accidents. In the machinery factors, failure of main engine and electrical power, failure of lubricating oil system, failure of navigation equipment, failure of rudder, failure of hull equipment and failure of propulsion should be considered. Finally, the navigational factors are discussed. This factor can contribute to the accident in the Strait of Malacca. Inappropriateness of ship operation regulation management, inappropriateness of crew manning, inappropriateness of navigational aid are important variable that should be evaluated in order to increase the navigational safety in the marine traffic.

To assess the danger score, criteria of human factors, machinery factors and navigational factors could not be evaluated using AIS data. These criteria were determined from a questionnaire. The questionnaire was distributed among the navigators who have experienced passing through the Strait of Malacca. As a complex system with multiple subjects and multiple levels of ship safety navigation, an evaluation index of ship navigational safety was compiled to make the levels more certain and accurate using AIS data. The process of the assessment is as follows:

At first, the weight of the evaluation index of each criterion (ship condition, human factors, environmental factors, machinery factors and navigational factors) and its related sub-criteria are established using AHP. Therefore, the value of the function of sub-sub-criteria is determined based on AIS data.

In order to obtain and create the model of ship collision in the Malacca Straits using Fuzzy method, ten scenarios have been established based on AIS data, GIS and other data source. Firstly, the classification of the ship's behavior such as type of ship, ship condition, characteristics of the area, distance between vessels, etc. were analyzed based on AIS data and GIS. Therefore, interviews with

the navigators that have experienced passing through the Malacca Straits have been conducted. The scenarios are also defined based on previous literature related to the safety of navigation in the Malacca Straits.

The scenarios with higher defuzzified values are considered to be more risky. Human error has the highest risk ranking. It is respectively followed by crossing situation, head on situation, short distance between vessels, speed of own ship and target ship, high traffic density, overtaking situation, error of navigation, bed weather condition and failure of machinery and electrical system. This result, called fuzzy risk ranking, is very important as it gives useful information to the navigators when passing through the Malacca Straits. It is also useful for navigators in order to prevent from accidents and to reduce the ship's collision risk in the Malacca Straits.

The risk assessment in safety of navigation is composed of two main activities: probability modeling and consequence modeling. The probabilities have been established based on AIS data and hazard analysis. The factors analyzed in assessing the ship collision probability are the head-on situation, crossing situation, overtaking situation, and traffic density, based on AIS and GIS.

Based on AIS data, the scenario of risk assessment have been carried out with different time with actual data. The risk level has been established in Head on condition, crossing condition and overtaking condition. scenario taken in the time which have high traffic area, on 2.00h, 10.00h, and 22.00h.

（別紙１）　　論文審査の結果の要旨

氏名	Muhammad Badrus Zaman		
論文題目	Implementation of Automatic Identification System (AIS) for Analysis of Marine Traffic Safety ＡＩＳデータの海上交通安全性評価への応用に関する研究		
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要　　旨

概要

マラッカ海峡はインドネシア、スマトラ島の東岸とマレー半島の西岸の間に位置し、航路の南東端はシンガポール海峡へと繋がっている。その長さは約 800km に及びマラッカ海峡は国際航海に利用される最も長い海峡である。この海峡はインド洋と東シナ海を結び、中東からアジア諸国への最短石油輸送ルートを形成しているが、この海域は船舶の航行密度が高い危険海域として分類されており航行安全性を高めることが大変重要視されている。本研究はこのマラッカ海峡を対象として、実際の航行船舶の動態を示すAIS（船舶自動識別装置：Automatic Identification System）データを海上交通の安全性評価に応用しようと試みたものである。

この研究論文は６つの章から構成されている。まず第１章では研究背景および対象水域であるマラッカ海峡の概要について述べている。

第２章では今回解析の対象としたマラッカ海峡のAISデータを受信する装置の内容や含まれる情報とその取扱い、さらに船舶航行安全性への応用についての概要を説明している。

第３章ではAISデータを活用して、船舶の動的性能、人的要素、環境的要素、機関的要素及び航行要件などにより示される危険度スコアを示す手法について論述している。すなわち、まず関連する研究事例のレビューにより既往研究での限界点について説明を行い、次に、マラッカ海峡におけるAISデータの解析と特徴を述べ、さらにこの研究で導入したAHP(階層化意思決定法：Analytic Hierarchy Process)の考え方の概要と、このAHP手法を導入するに際しては、含まれる多くの要素について、重みづけの方法などについて論述している。さらに、このAHPを活用して、DS（航行の危険度指数：Danger Score）を表わす新たな手法の提案と解説を行っている。このDSは、船の種別や長さなど船体の情報、潮流や風、他船との相互関係などの環境情報、機関情報などから構成されているが、実際のマラッカ海峡を例として、その時間変化ついてコンテナ船やVLCCを例にとり解析評価例を示している。

第４章では船舶の衝突事故に関連してFMEA（故障モードとその影響の解析：Failure Mode and Effect Analysis）手法およびFSA（総合安全性評価：Formal Safety Assessment）手法をマラッカ海峡の海上交通に適用する解析手法について述べている。いずれも取り扱う海上交通の評価には、既往研究分析などに基づきファジー理論を加味した手法が有効であるとしている。FSA解析では、ハザードの定義などからなる４つのステップで表現し、次に、マラッカ海峡における事故分析を行い、それらに基づいて今回導入したファジー理論のおけるメンバーシップ関数の検討および設定手法について述べている。

第５章では安全航行に関する評価手法について言及している。ここではマラッカ海峡に係るAISデータに基づいてCOLREG（国際海上衝突予防規則に関する条約）に沿ったリスクモデルの提案を行い、通航過密量と危険度解析を行っている。また異なる時間帯や船首方向、行き合い、追い越しなどの遭遇状況について危険度をマトリックス表示して解析する手法を確立した。

第６章では特に3～5章の結果について総合的な考察を加えている。その結論として、AISデータの活用がこのような海上交通の評価解析には重要であること、今後コストも考慮した安全性評価が必要であること、さらには、衝突防止にこのAISデータを活用していくことの必要性などに言及している。

そして第６章では本研究の結論として、マラッカ海峡を対象として海上交通の安全性にかかる研究を実施していたが、AISデータがこのような海上交通の危険度の解析評価に重要であること、AHPやFMEA手法が評価手法として使用できること、特にファジー理論の適用が重要であることなどを示した。

氏名	Muhammad Badrus Zaman

なお、本論文を構成する主な投稿論文は査読付学会論文２編、国際学会プロシーディング３編に次の通りまとめられ公表されている。

(1) Zaman, M.B., Kobayashi, E, Wakabayashi, N., et al.: Usage of Automatic Identification System (AIS) for Evaluation of Marine Traffic Safety in the Malacca Straits. Proceeding of AMEC-2010 – Advance of Maritime Engineering Conference, Singapore, pp. 462-467, 2010.(国際学会プロシーディング)

(2) Zaman, M. B., Kobayashi, E., Wakabayashi, N., et al.: Fault tree Analysis Model of Tanker for Formal Safety Assessment (FSA) in The Malacca Straits Based on AIS Data, Proceedings of the International Symposium of Marine Engineering (ISME), Kobe, Japan, pp. 1541-1546, 2011. (国際学会プロシーディング)

(3) Zaman, M.B., Kobayashi, E., Wakabayashi, et al: Ship Collision Probability for Formal safety Assessment Based on AIS Data In The Malacca Straits, Asia navigation Conference (ANC), Wuhan, China, pp. 486-497, 2011. (国際学会プロシーディング)

(4) Zaman, M.B., Kobayashi, E., Wakabayashi, N., et al.: Implementation of Automatic Identification System (AIS) for Evaluation of Marine Traffic Safety in Strait of Malacca using Analytic Hierarchy Process (AHP), 日本船舶海洋工学会論文集, 第16号, pp.141-153, 2013.

(5) Muhammad Badrus Zaman, Eiichi Kobayashi, et al.: Fuzzy Model for Risk Evaluation of Ship Collisions in the Malacca Strait Based on AIS Data, Journal of Simulation, Vol.9, pp.1-14,2013.

以上述べてきたように、本論文は、AISのデータを活用し海上交通の危険度の評価をマラッカ海峡を例としてとりあげ行おうとするもので、このような手法は、今後の海上交通のありかたや管制を学際的に論ずるためにきわめて重要なものである。このような研究は既往事例が少なく、独創性があり、また十分吟味された解析手法により評価している点で信頼性も高い。よって本論文は，学位論文に値するものと認める。