Research Highlight 1: Experiment Design of Impact Analysis of Large Ships on Ship Traffic in the Straits of Malacca and Singapore, by Dr. Xie Yajuan (Track Leader: Professor MENG Qiang)

Background

The Singapore Strait is part of the Straits of Malacca and Singapore (SOMS), and it is also one of the most important straits. About 100,000 ships pass through Singapore Straits every year. SOMS is the shortest strait which links Indian Ocean and Pacific Ocean, and also the most important shipping waterway connecting Asian, African, Australia and European countries. SOMS is therefore the choke point between the Pacific Ocean and the Indian Ocean as the main shipping channel.

In order to enhance the safety of navigation in the Strait of Singapore, in 1998 the International Maritime Organization (IMO) has adopted STRAITSREP – the Mandatory Ship Reporting System in the Straits of Malacca and Singapore that was proposed by Indonesia, Malaysia and Singapore. STRAITSREP divided the straits into nine sections, as shown in Figures 1 and 2.

In SOMS, the narrowest distance between points is only 2.8 km, and the depth in the straits ranges between 22m and 157m, meanwhile there are islands and shoals in the straits. These natural conditions make it difficult and risky for large vessels to sail in the straits.

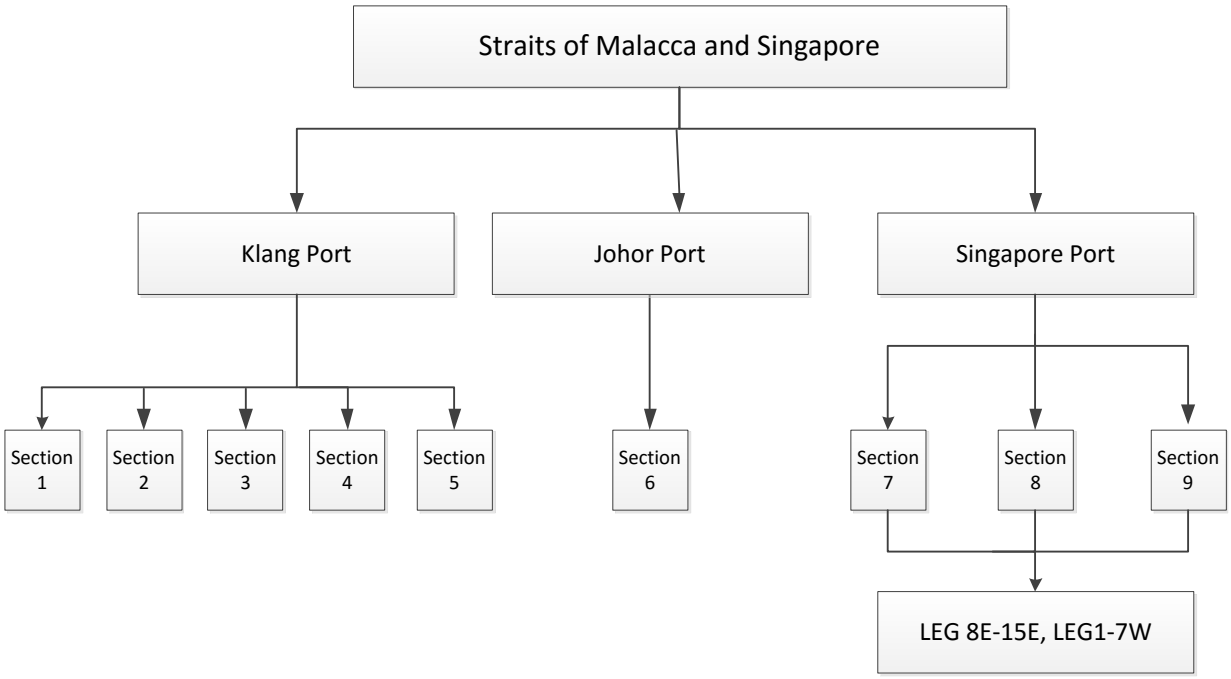

Figure 1 STRAITSREP sections in the Straits of Malacca and Singapore

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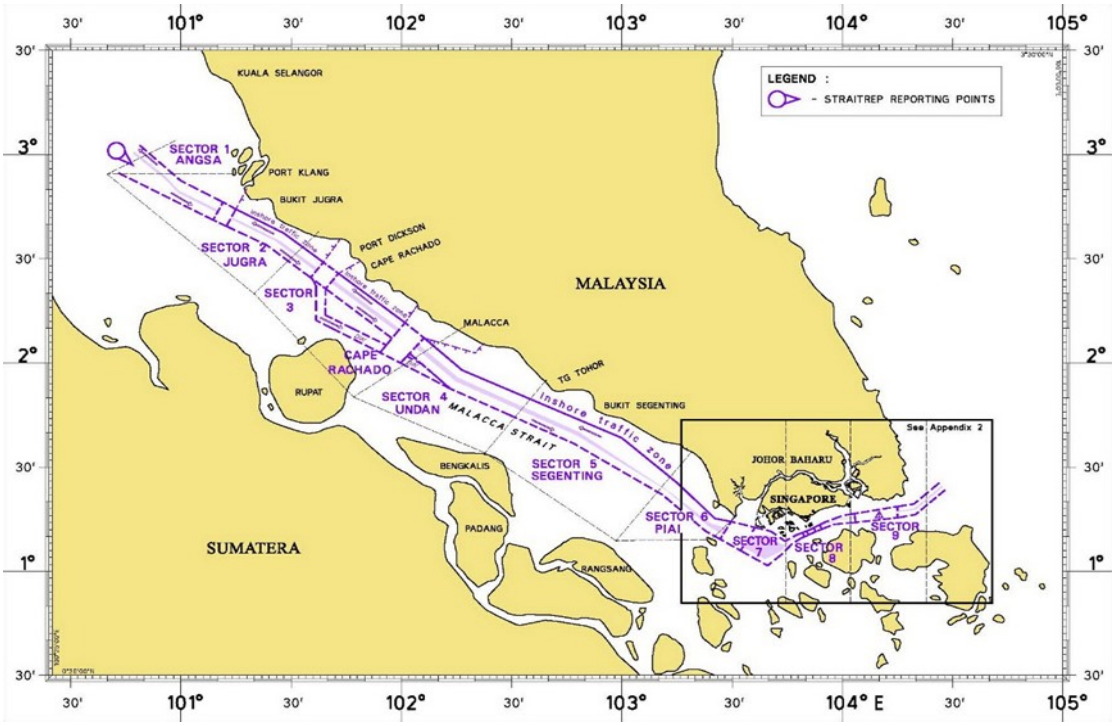

Figure 2 The Straits of Malacca and Singapore

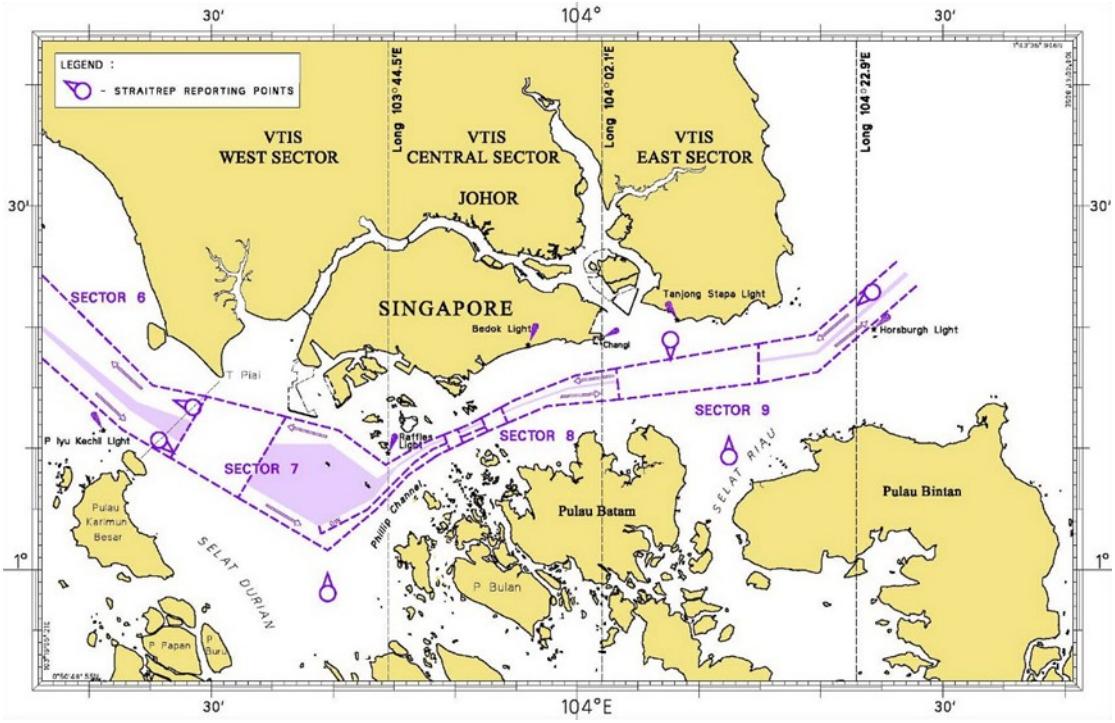

Figure 3 The Singapore Strait

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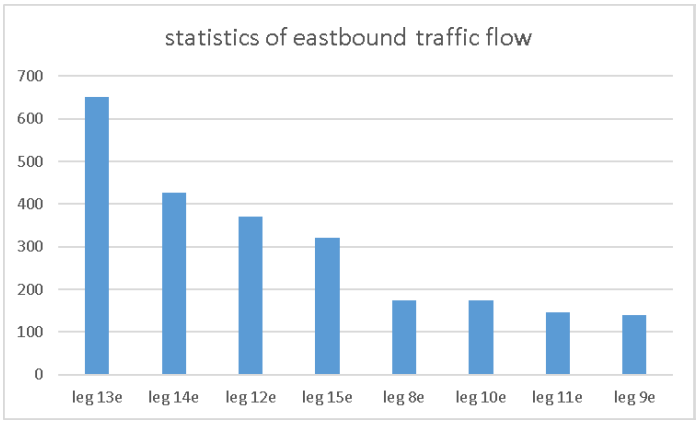
Objectives

In order to look into the patterns of behaviors of sailing large ships through SOMS, we conduct simulations and set different scenarios in the Singapore Strait for experiments. The experiments are conducted by experienced captains on Dalian Maritime University (DMU) ship navigation simulator platforms, and the experiment results are expected to record behaviors of the captains maneuvering large ships. With these results, we will extract the rules of collision avoidance from the behaviors, which can provide reliable support to the simulation platform we build and make the model reflects actual results more precisely, meantime can support decision making for Singapore Maritime Bureau in the management of the Straits.

Analysis of Historical AIS Data in the Singapore Strait

The study area for experiment design is the Singapore Strait, as shown in Figure 3 from section 7 to section 9, where Legs 4W, 5W, 11E, 12E are the narrowest parts in the Singapore Strait. Thus main efforts of collision avoidance is focused on this area. The design of the experiments is based on the safety analysis and the results of safety assessment models according to historical AIS data.

Experimental program design is based on the traffic statistics of AIS data from October 1 to October 7 2013. Before the experimental program, we performed statistical analysis with the data extracted from each leg of the ship traffics. Firstly, the traffic flow on each leg is counted as once when one ship completes two passages through the leg from in and out two directions. Secondly, historical AIS data could provide traffic flow information of such detail, thus we could calculate the traffic flow based on AIS data. Statistical results are shown in Figures 4 and 5.



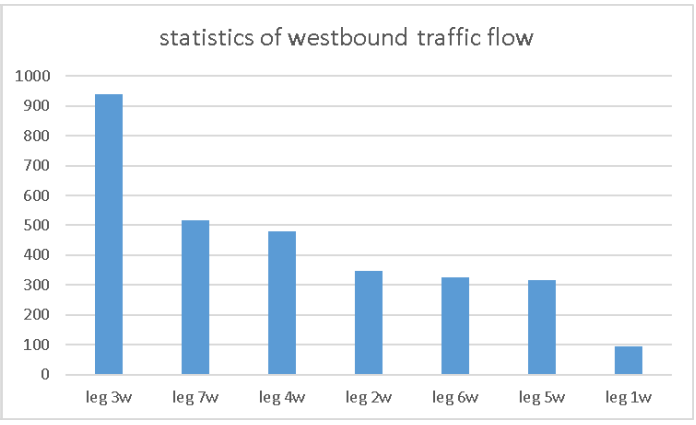


Figure 4 Statistics of traffic flow of eastbound legs

Figure 5 Statistics of traffic flow of westbound legs

According to the above results, we take the legs with most traffic flow as experimental areas, and they are LEG 13E, LEG 3W, LEG 14E, LEG 7W, LEG 12E, and LEG 4W.

The second basis for the experimental design is safety assessment platform we developed. The platform can import historical AIS data, perform AIS data analysis, present navigation dynamic track of ships, make assessment of possible collision types and show the location on the map. The platform is shown in Figures 6 and 7.

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Analysis of Historical AIS Data in the Singapore Strait

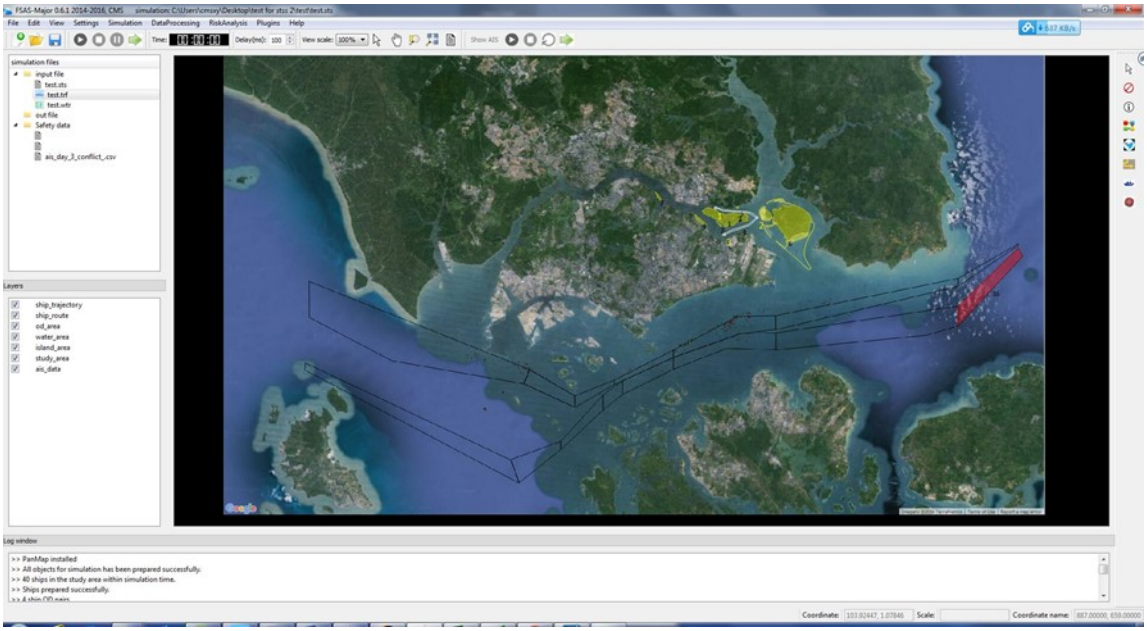

Figure 6 Safety assessment platform and the Singapore Strait

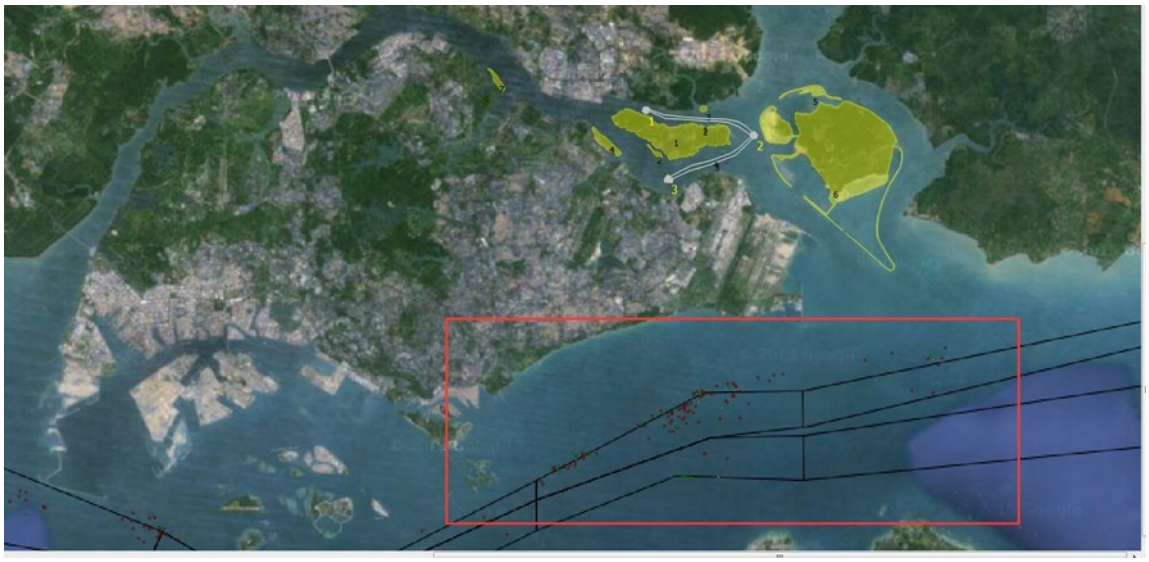

Figure 7 Possible collision types and locations of collisions based on historical AIS data

Historical AIS data analysis results of the safety evaluation platform shows that the collision type of the highest incidence is crossing, followed by overtaking, and then contact type. Therefore, the design of experimental program focuses on crossing collision type, overtaking types mainly. Meantime, ship contact and head-on scenario are considered in the experiment design.

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Ship Classification and Parameters

For the experiments carried out in DMU, six types of ships are examined according to the existing ship database in the ship navigation simulator for this experiment. Table 1 lists all the six ship types.

Table 1 Ship classification in the Singapore Strait

No.	Ship types	Notes
1	LNG/LPG	Liquefied Natural Gas/ Liquefied Petroleum Gas ships
2	OT	Oil tanker
3	RoRo	Roll-on Roll-off
4	BC	Bulk Carrier
5	GC	General Cargo
6	Container ship	Container ship

In the experiment, we target on three ship types of LNG / LPG, OT and containership that could interactive while sailing through the straits and getting close to each other.

Scenario Classification

The possible scenarios of ship interactions could be classified into below four types, and Figure 8 shows the detail.

- Head-on scenario
- Overtaking scenario
- Crossing scenario
- Multi-vessel interaction scenario

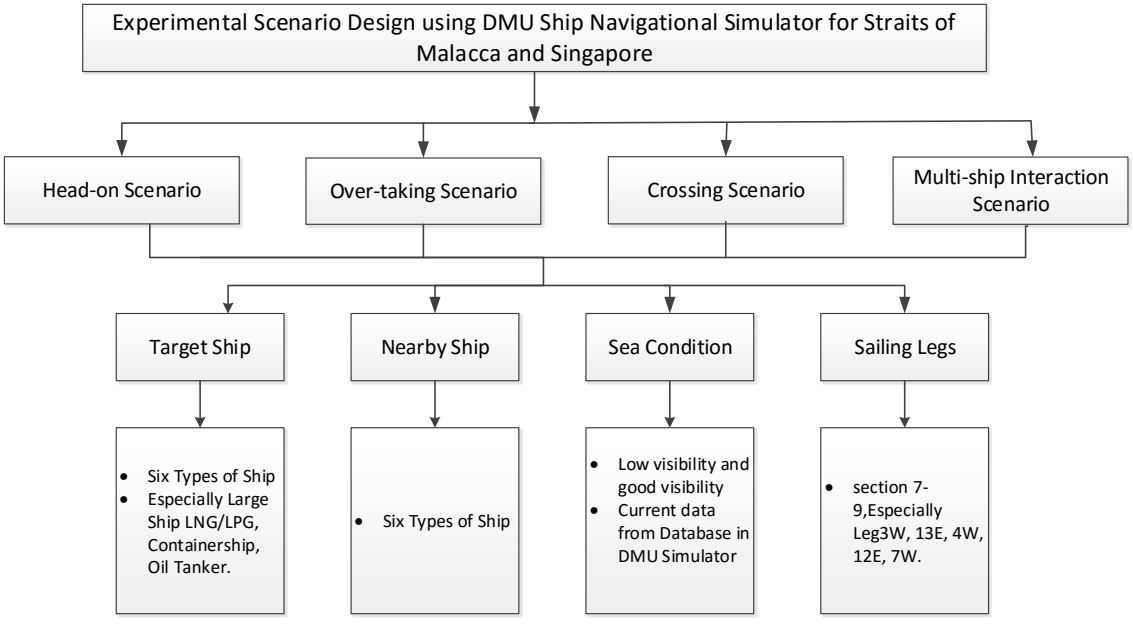

Figure 8 Navigation scenario classification and scenario parameters

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Scenario Classification

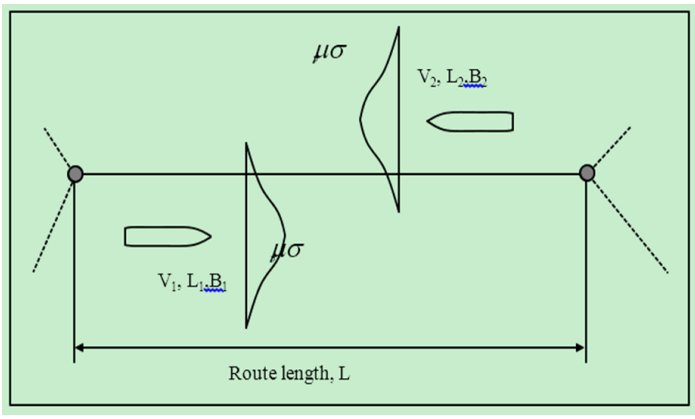

Figure 9 Head-on scenario between two vessels

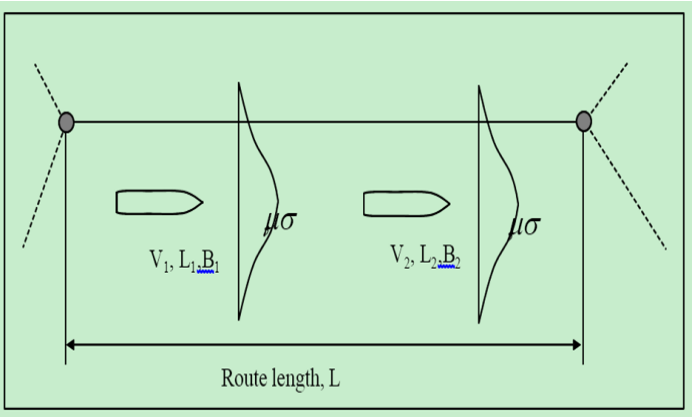

Figure 10 Overtaking scenario between two vessels

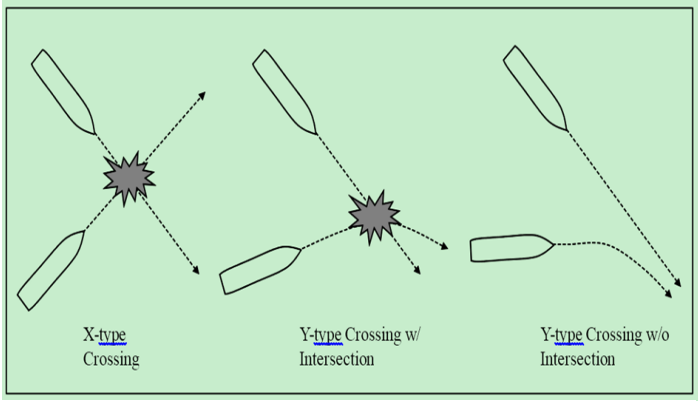

Figure 11 Crossing scenario between two vessels

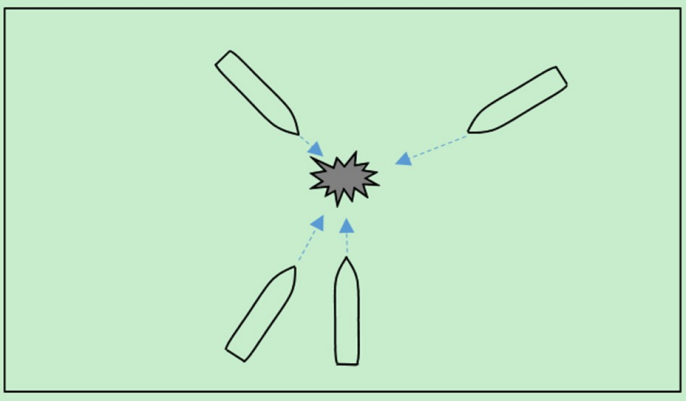

Figure 12 Multi-vessel interaction scenario

Parameters in Experiment Scenarios

- **Characteristics of target vessels and nearby vessels**
  The characters considered in the experiment include: vessel type, vessel name, length of vessel, breadth of vessel, DWT, draught, loading status, start point of vessel, end point of vessel, course, speed, and sailing distance. In this experiment design, the loading status of all the vessels are F, referring to full of loading status.
- **Sea condition**
  Generally, visibility at sea can be classified into four grades, namely poor visibility (less than 0.5 nautical miles), low visibility (2-5 nautical miles), good visibility (greater than 5 nautical miles), and optimum visibility (greater than 10 nautical miles).

  The visibility of Singapore Strait sometimes is influenced by haze from Indonesia and heavy rains in Singapore. Considering these characteristics, the visibility in Singapore Straits is divided into two levels, namely low visibility (2-5 nautical miles) and good visibility (greater than 5 nautical miles).

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Parameters in Experiment Scenarios

For wind and waves, because we don't have wind or waves data available, we will use the data from the database of DMU ship navigation simulator.

Experimental Program Design

In addition, we also consider sea and weather conditions for the experiment design. Since the impacts from wind and waves in the Singapore Strait are relatively small, especially to fully loaded ships, thus we mainly consider current and visibility when design the experiment. Two levels of visibility and current are classified to distinguish the different levels of impacts to ship navigation safety, and they are as following.

- Low visibility and steady stream
- Good visibility and steady stream

Based on the above statistics analysis and corresponding assumptions, we design 63 scenarios for experiments in total, and we use ArcGIS to draw the case on map as visual reference for each scenario. In each scenario, we set initial values to parameters for target vessel and other vessels in the vicinity, and the parameters include coordinate position, velocity, course, sailing distance, and collision / contact types. All such information is available in DMU ship navigation simulator.

Experimental Output

We design different ship sailing scenarios in Singapore Straits for experienced captains to conduct experiments on DMU ship navigational simulator.

The captains' driving behavior will be recorded in sailing data as experimental results, from which we further extract the collision avoidance rules. All of the rules can be used as the input of the simulation platform we build to make the model to reflect actual ship sailing behavior more precisely, also can provide decision support for Singapore Maritime Bureau in the management of the Straits.

The output we expect to obtain from experiment are of five categories, as shown in Table 2. They are mainly: Captains' reactions in the designed experimental scenarios, extractions of captains' behavior including time, location, the distance between the target ships and the ships in the vicinity, recorded sailing trajectory data which is similar to AIS ship sailing trajectory data.

Table 2 Captains' behaviors and relative data recorded by ship navigational simulator

No.	Captains' behaviors	Data record
1	speed up	Time, location, distance with ships in the vicinity
2	speed down	Time, location, distance with ships in the vicinity
3	keep current status	Distance with ships in the vicinity
4	change course	Time, location, distance with ships in the vicinity
5	Re-planning route to originally planned route	Ship sailing trajectory data (similar to AIS data)

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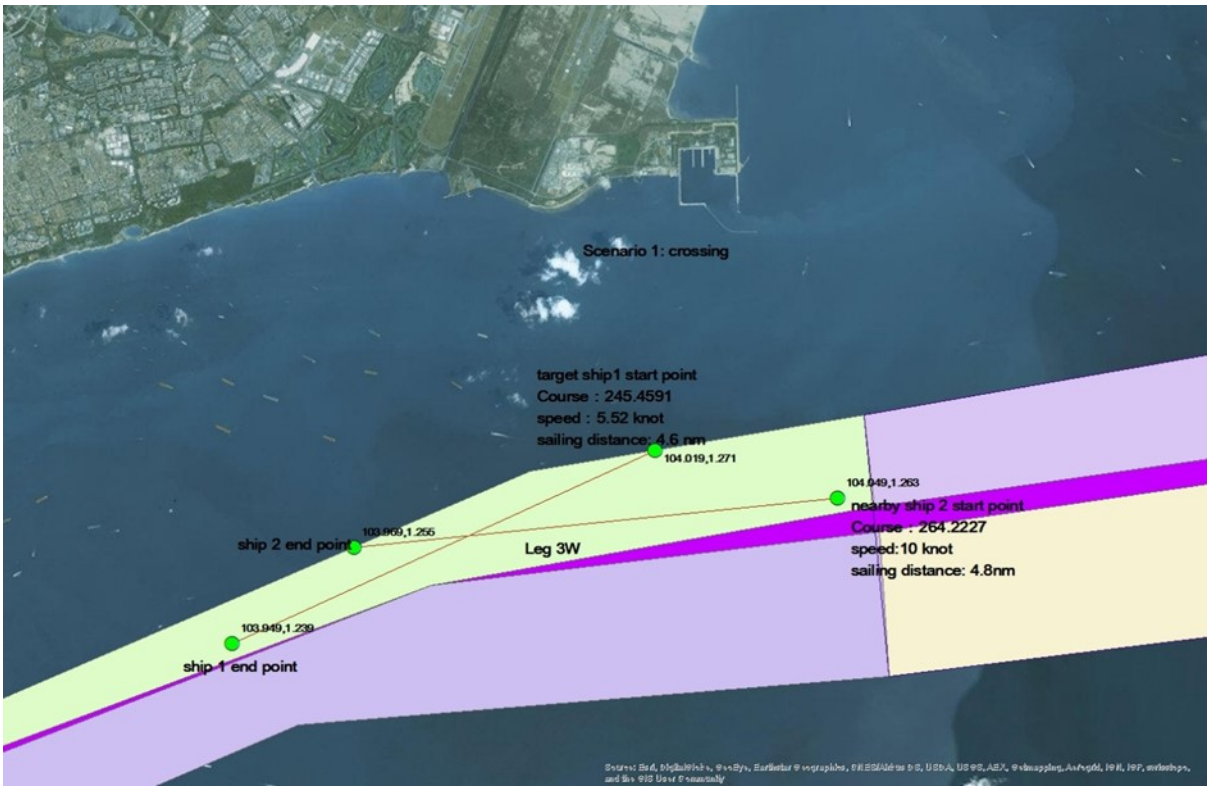
Experiment Design Examples

- Example 1

Experi-mental scenario	Encoun-ter type	Course (eastbound/ westbound)	Target ship start point, end point, type, model, course, speed (knots), sailing distance	Location of Ship in the vicinity , start point, end point, type, model, course, speed (knots), sailing dis-
1	Crossing	**Westbound** 3W	LNG/LPG-2 104.019,1.271 à 103.949,1.239 Course：245.4591 Speed: 5.52knots Sailing distance: 4.6nm	LNG/LPG-265 104.049,1.263 à103.969,1.255 Course：264.2227 Speed: 10 knots Sailing distance: 4.8nm



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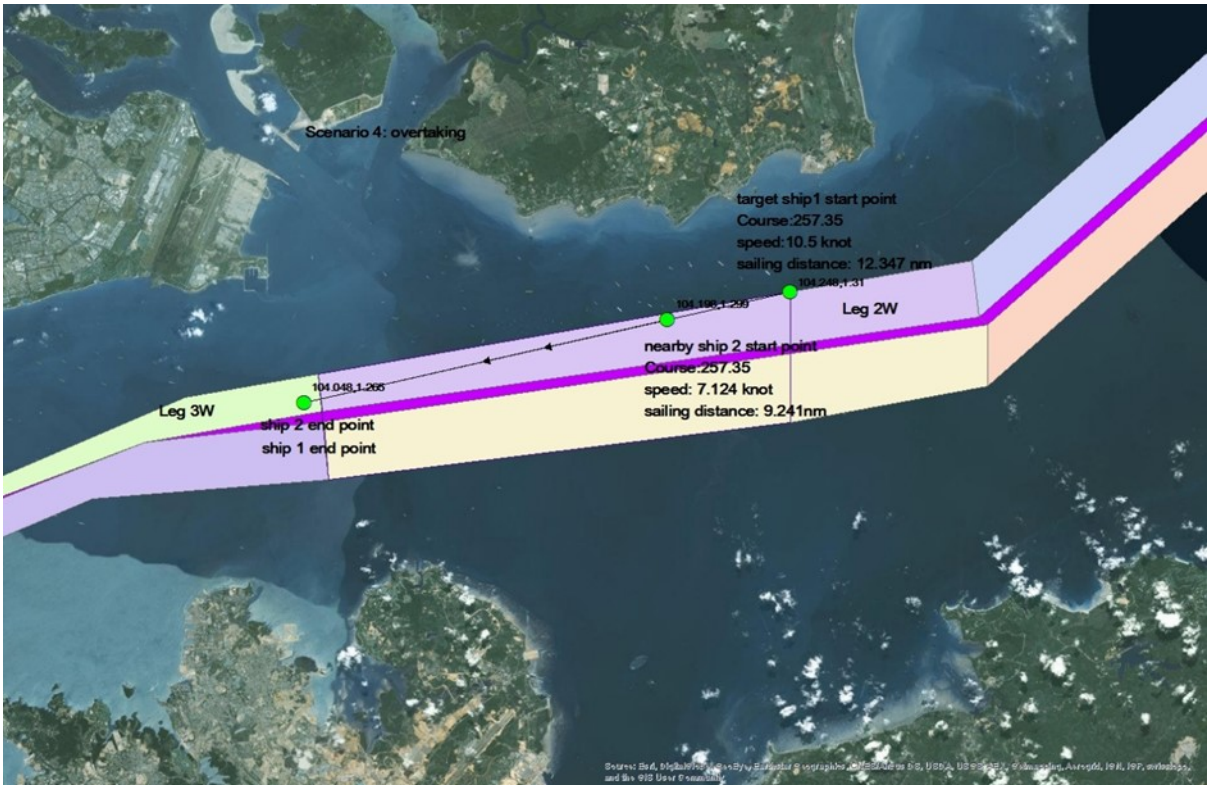
Experiment Design Examples

- Example 2

Experimental scenario No.	Encounter type	Course (eastbound/ westbound)	Target ship start point, end point, type, model, course, speed (knots), sailing distance (nm, nautical miles)	Location of Ship in the vicinity , start point, end point, type, model, course, speed (knots), sailing distance
2	Overtaking	**Westbound** 3W	Oil Tanker 30WAN 104.248,1.31 à 104.048,1.265 Course：257.35 Speed: 10.5knots Sailing distance: 12.347nm	RoRo Yulong 104.198,1.299 à103.952,1.243 Course：257.35 Speed: 7.124knots Sailing distance: 15.134nm



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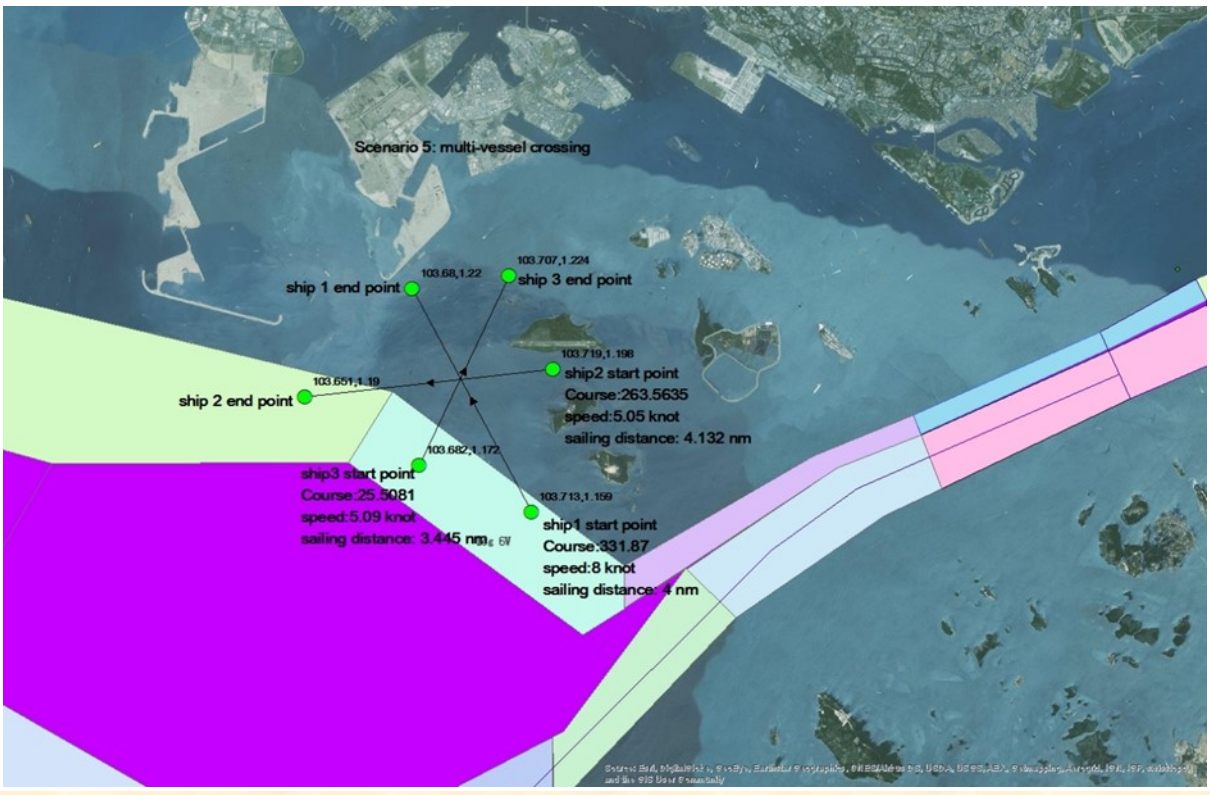
Experiment Design Examples

- Example 3

Experimental scenario No.	Encounter type	Course (eastbound/ westbound)	Target ship start point, end point, type, model, course, speed (knots), sailing distance (nm, nautical miles)	Location of Ship in the vicinity , start point, end point, type, model, course, speed (knots), sailing distance
3	Multi-vessel interaction	**Westbound 6**W and port waters	**Target ship** LNG/LPG-265 103.713,1.159 à 103.68,1.22 Course：331.87 Speed: 8knots Sailing distance: 4nm	**Nearby ship** containership ULCS 103.719,1.198 à 103.651,1.19 Course：263.5635 Speed: 5.05knots Sailing distance: 4.132nm **Nearby ship** general cargo **1WAN** 103.682,1.172 à 103.707,1.224 Course：25.5081 Speed: 5.09knots Sailing distance: 3.445nm



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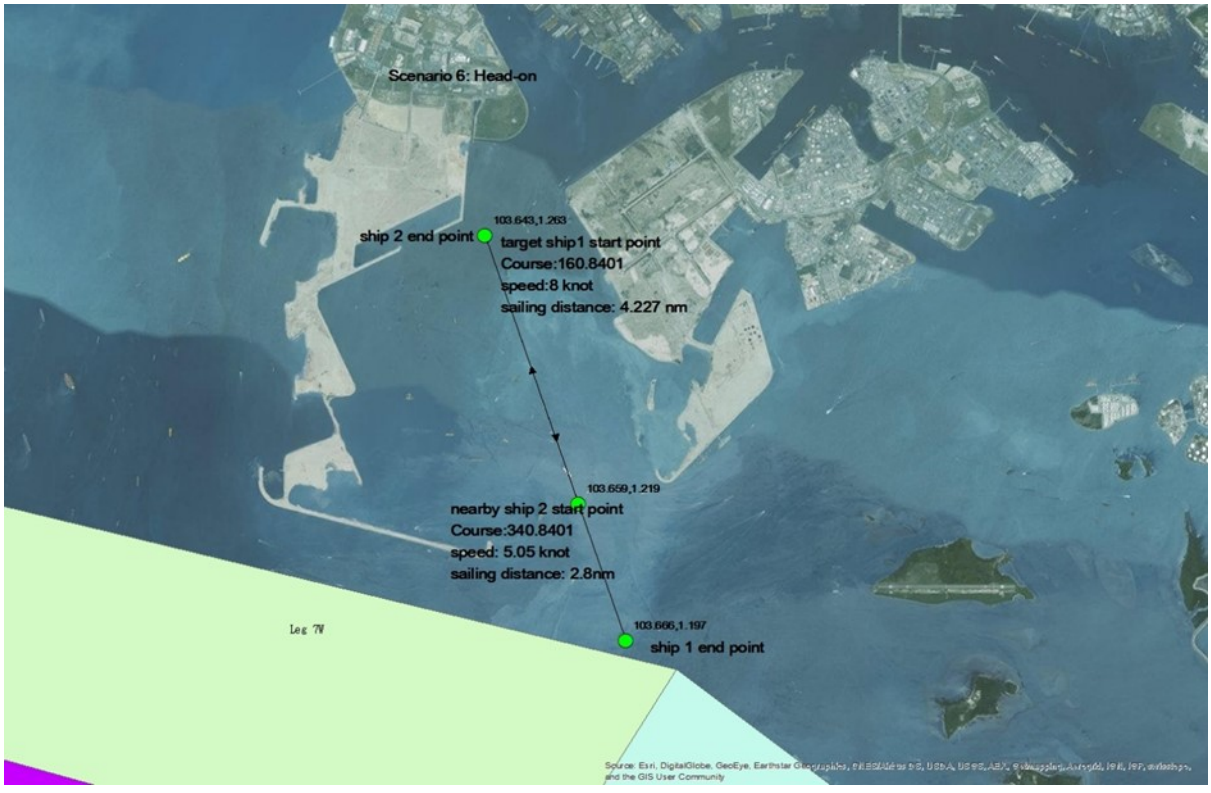
Experiment Design Examples

- Example 4

Experimental scenario No.	Encounter type	Course (eastbound/ westbound)	Target ship start point, end point, type, model, course, speed (knots), sailing distance (nm, nautical miles)	Location of Ship in the vicinity , start point, end point, type, model, course, speed (knots), sailing distance
4	Head on	**Port waters**	Oil Tanker **YunHong** 103.643,1.263 à 103.666,1.197 Course：160.8401 Speed: 8knots Sailing distance: 4.227nm	LNG/LPG-2 103.659,1.219 à 103.643,1.263 Course：340.8401 Speed: 5.05knots Sailing distance: 2.8nm



Conclusion and Future Work

- We can extract the rules of captains' behaviors during the sailing in Singapore Straits by deploying decision tree method after we get the experiment results based on the experiment design.
- We will apply the extracted rules in our simulation model to make assessment on the impact of large ships in Singapore Straits.

Research Highlight 2: Formal Safety Assessment System for Ship Traffic in Port Waters – Grounding Sub-system , by Dr. LI Wenhao (Track Leader: Professor MENG Qiang)

Background

The shipping industry has witnessed fast growth in the last three decades, where the shipping traffic is becoming more complex, and the size of ships are becoming bigger and bigger. Under such circumstance, the challenge for shipping safety, i.e., the increment in shipping hazards including grounding, collision, contacting, etc., is becoming a more serious problem than ever before. Specifically, in hub port water areas and the traffic routes nearby, such as Singapore port and Singapore Strait, the high shipping traffic and narrow/shallow route have made the shipping safety issue even more severe.

To enhance maritime safety, the Formal Safety Assessment (FSA) methodology is proposed by the International Maritime Organization (IMO). By using risk analysis and cost benefit assessment, FSA can be used as a tool to help in the evaluation of new maritime safety regulations or in making a comparison between existing and possibly improved regulations. In order to build a formal safety assessment system to assess the ship safety in waters of Singapore water areas, this project is funded by MPA in 2014.

Objectives

The project focuses on development of a FSA system for ship traffic in port waters. Where one of the sub-systems named FSAS-Grounding is implemented specifically for the data processing, filtering and grounding model implementation.

Methodology

We have designed our grounding model by following some previous pioneering studies (e.g., Fujii et al., 1974; Pedersen, 2002; Kaneko, 2012), the proposed vessel trajectories & seabed geometry-based grounding frequency estimation model is developed based on the concept of grounding candidate, which is defined as: a situation when a ship deviates from its planned route and it sails without corrective action such as changing course or speed before a grounding accident happens (Kaneko, 2012). In addition, different from the ship domain used for ship collision model, in the grounding model, we define a new 3D ship domain for ship grounding by using ship information including length, beam and draft.

The proposed model can be divided into a multi-stage procedure:

i. Build digital elevation model (DEM) based on the seabed geometry and port layout;
ii. Determine vessel coordinate by using analytical geometry;
iii. Formulate the piecewise ship elevation function based on DEM;
iv. Calculate the number of grounding candidates according to the elevation domain conflict;
v. Estimate the grounding frequency.
vi. Estimate the grounding consequence by grounding frequency and accident factors.

System Features

FSAS-Grounding contains the following features:

1. For conducting grounding risk assessments with comprehensiveness and accuracy, FSAS-Grounding has adopted a novel grounding model, which is simple, generate low computing overhead and suitable for processing big AIS data. In addition to the parameters that are widely used in existing grounding models such as draft, sounding data, the new model also adopt the tide information in port waters.

Research Highlight 2: Formal Safety Assessment System for Ship Traffic in Port Waters – Grounding Sub-system , by Dr. LI Wenhao (Track Leader: Professor MENG Qiang)

System Features

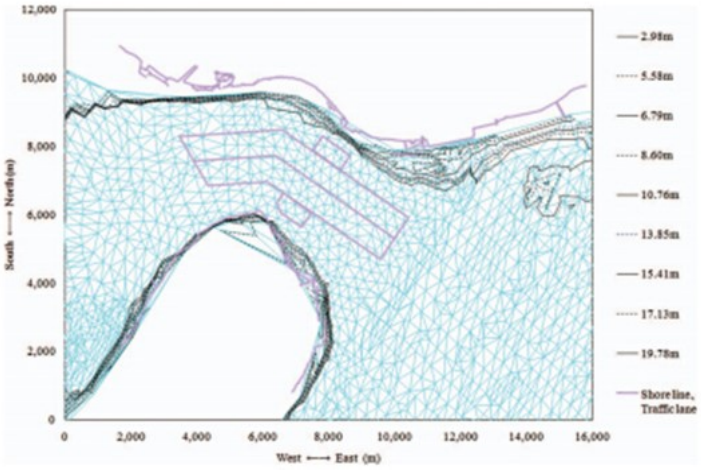


Figure 1 Vector based triangular irregular network (DEM) for the sea water

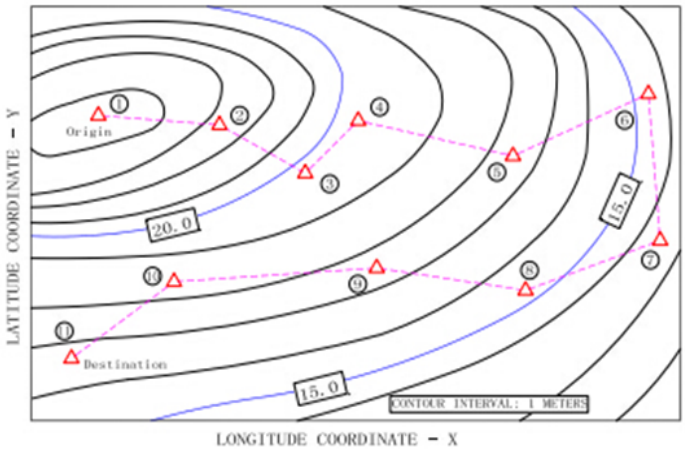


Figure 2 Grounding model demonstration using contour lines

2. Fully GUI based user friendly interface for conducting all the logic and management functions, including Project Management, Display Management, Log Management, Grounding Frequency/Consequence Assessment, Result Analysis and Additional Tools.

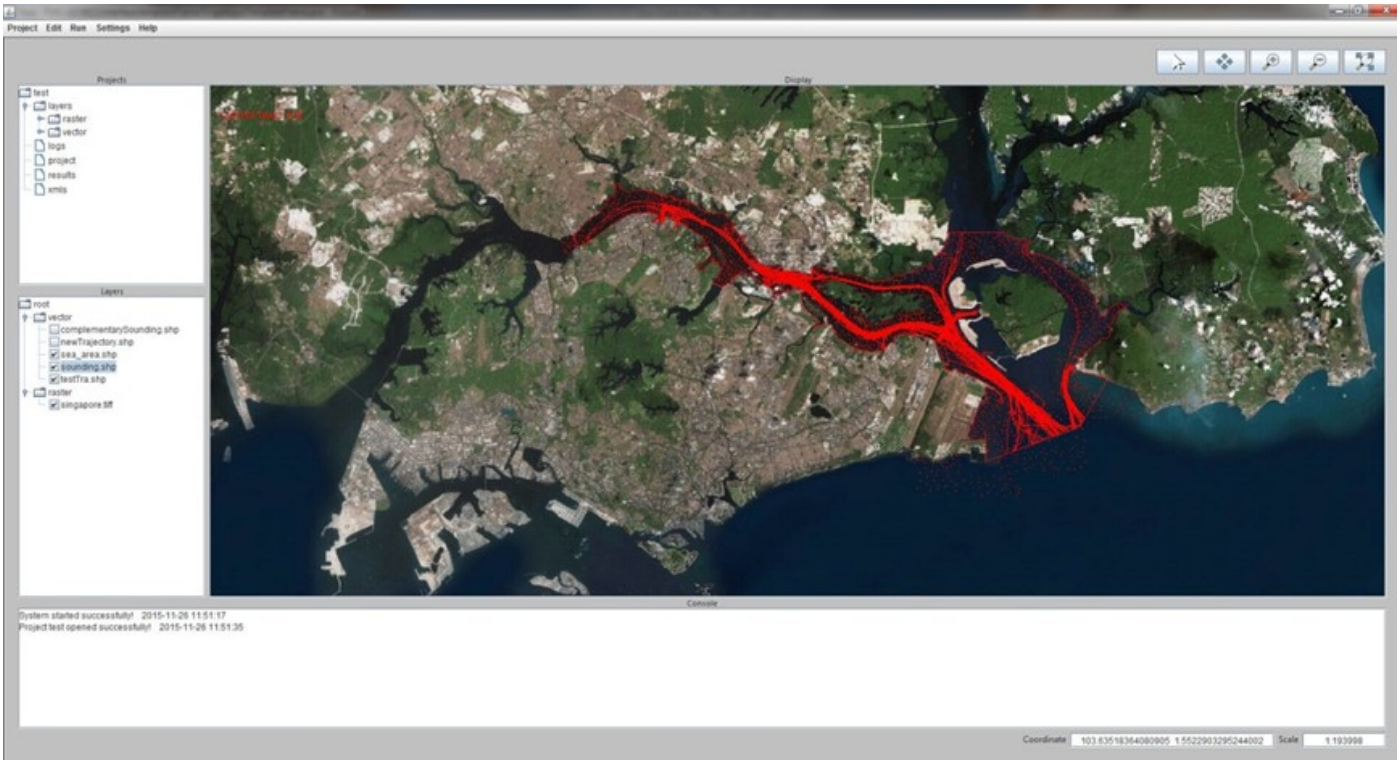


Figure 3 User interface of FSAS-Grounding

Research Highlight 2: Formal Safety Assessment System for Ship Traffic in Port Waters – Grounding Sub-system , by Dr. LI Wenhao (Track Leader: Professor MENG Qiang)

System Features

3. To deal with the grounding assessment in water areas with sparse sounding data, such as undeveloped water areas, two novel algorithms are proposed, which are the sounding supplementary algorithm for enhancing the sounding density and the triangle interpolation algorithm for calculating the under-keel clearance of the ship.

Figure 4 Trajectory enhanced sounding data for the study area

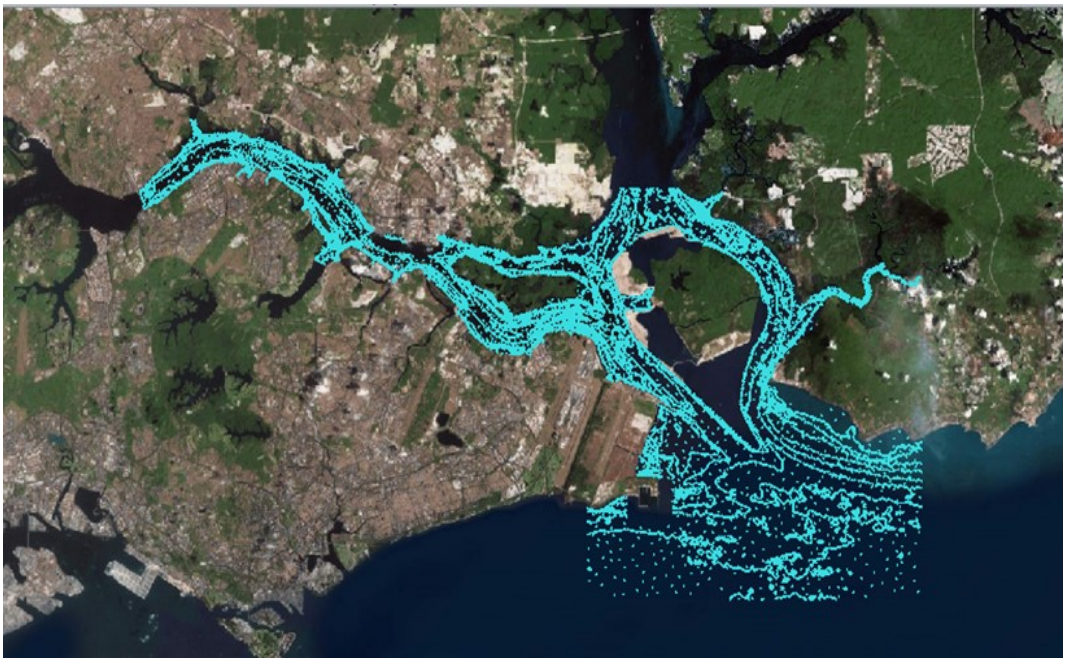
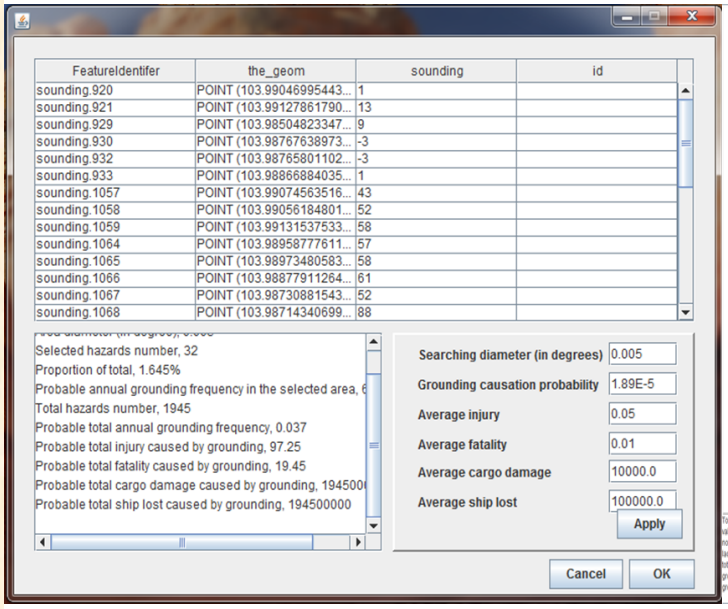


Figure 5 Contour enhanced sounding data for the study area

Research Highlight 2: Formal Safety Assessment System for Ship Traffic in Port Waters – Grounding Sub-system , by Dr. LI Wenhao (Track Leader: Professor MENG Qiang)

System Features

4. By leveraging the big AIS data and the data analysis methods, FSAS-Grounding is able to conduct large scale grounding risk assessments with high efficiency and generate results with high analytical value.



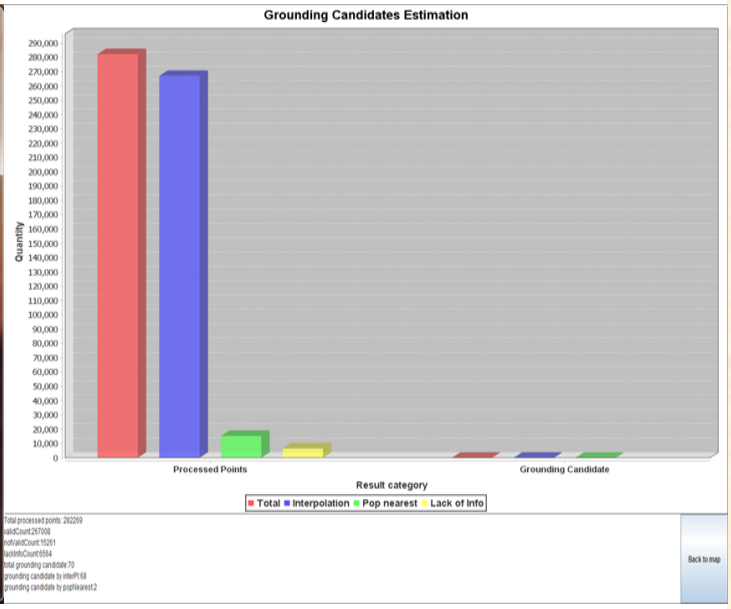


Figure 6 Grounding frequency and consequence result

Figure 7 Chart analysis of the grounding assessment result

Conclusions

By leveraging the novel grounding model and latest software development technologies, FSAS-Grounding provides a high performance grounding analysis platform with a user-friendly GUI based operating interface, and provides comprehensive functions that facilitate the visual presentation of the assessment result and statistical analysis. By using this system along with other modules of the FSAS system, the generated report can facilitate the port development planning and many other works within the port management and marine traffic management departments of Singapore with efficiency and flexibility.

Published Technical Papers (with Abstracts)

1. **Haobin Li, Giulia Pedrielli, Loo Hay Lee, and Ek Peng Chew (2016), Enhancement of Supply Chain Resilience through Inter-Echelon Information Sharing.** ***Flexible Services and Manufacturing Journal.***

Abstract:

Supply chains in the globally interconnected society have complex structures and thus are susceptible to disruptions such as natural disasters and diseases. The impact of the risks and disruptions that occur to one business entity can propagate to the entire supply chain. However, it has been proposed that cooperation amongst business entities can mitigate the impact of the risks. This paper aims to investigate the value of information sharing in a generalized three-echelon supply chain. The supply chain model is built in a system dynamics software, and three decision-making rules based on different levels of information sharing are developed. Performances of the three ordering policies with shock applied are compared. The results of the experiments prove the value of information sharing in the supply chain when shock exists.

2. **Weng Sut Sou and Ghim Ping Ong (2016), Forecasting Global Maritime Container Demand with Integrated Trade–Transportation Modeling Framework.** ***Transportation Research Board, Pages 64-77.***

Abstract:

Global maritime trade has experienced increasing trade value and volume in recent decades. Most trade commodities are transported through seaborne containers. Therefore, the ability to forecast maritime container demand is important to policy makers for keeping their competitive advantage or to plan for infrastructure development. Numerous efforts have been made to forecast container demand, most such studies adopting an economic approach or a transportation model. Few studies have considered the forecasting of maritime container demand from an integrative economic trade–transportation modeling perspective. The study presented in this paper developed a quantitative demand forecasting approach to predict future seaborne container demand in the global context. This integrated forecasting framework uses the transportation-based four-step model coupled with economic and trade theories. Computable general equilibrium models based on economic theories were developed to derive the amount of trade flow between countries. Through the application of transportation mode choice models, the amount of seaborne trade between countries was then estimated. Statistical models with expert opinions were developed to convert commodity value into number of containers. The developed model framework was then used to study the container demand trends in several countries between 2008 and 2018. This case study found that the model framework could simulate global maritime trade and container demand and would be useful for planners in formulating relevant macroeconomic trade and transport policies.

3. **Zhang, Yiru, Qiang Meng, and Liye Zhang (2016), Is Northern Sea Route Attractive to Shipping Companies? Some Insights from Recent Ship Traffic Data.** ***Marine Policy 73, Pages 53-60.***

Abstract:

While the media vigorously propagates historic Northern Sea Route (NSR) transits and researchers demonstrate the viability of the NSR, current usage by the shipping industry has been neglected thus far. This study aims to analyse the current ship traffic at NSR using transit data and port call data. The results show that navigation season lasts for five months, and Arc4 and Arc5 vessels are used extensively. Some Asian countries are active participants in the transit activities. NSR seems to be more appealing to liquid, bulk and general cargo transportation. Currently, most activities are still domestic and destinational in nature. The paper provides real statistics that can add value to the viability analysis. It identifies key players of the transits, exhibits trade pattern at NSR, and presents facts that interest shipping companies.

Published Technical Papers (with Abstracts)

4. **Qiang Meng, Yiru Zhang, and Min Xu (2016), Viability of Transarctic Shipping Routes: a Literature Review from the Navigational and Commercial Perspectives.** ***Maritime Policy & Management, Pages 1-26.***

Abstract:

The continuous ice retreat in the Arctic has fueled speculations of new transarctic shipping routes to be operational soon. While the media vigorously propagates the great potentials of these routes, researchers have accessed the feasibility of opening of transarctic shipping routes from various perspectives; diverse and some polarized conclusions have emerged. This paper aims to critically review the studies that examine the necessary conditions and requirements that make transarctic shipping routes sufficiently viable. We mainly focus on two aspects: navigation conditions and commercial features. Selected studies are analyzed and compared in depth. Finally, possible future research directions are put forward. This article is a revised and expanded version of a paper entitled Viability of Transarctic Shipping Routes: An Overview, presented at the International Conference on 'Global Integration of Economies and Connectivity Development' in Taiwan on 31 August 2015.

5. **Yi Tao, Loo Hay Lee, and Ek Peng Chew (2016), Quantifying the Effect of Sharing Information in a Supply Chain Facing Supply Disruptions.** ***Asia-Pacific Journal of Operational Research, Volume 33, Issue 04.***

Abstract:

1.In this work, a system dynamics simulation approach is proposed to evaluate the effect of sharing information with partners in a supply chain when it is faced with supply-related disruptions which severely affect the product manufacturing. We focus on a simple two-echelon supply chain involving one retailer and two suppliers, and study the retailer's decision on allocating orders between the suppliers. Three specific settings of information sharing by the suppliers are investigated: (i) no information shared; (ii) information partially shared; and (iii) information completely shared. After establishing corresponding ordering policy under each setting, we conduct extensive numerical analysis to simulate shocks to suppliers' manufacturing capacity and calculate the resulting extra cost as measure of the effectiveness of information sharing. Simulation results show that with more information shared by suppliers, the retailer is able to make response to disruptions more accurately and timely, the negative impact of which thus can be reduced by larger extent, even though not completely eliminated.

6. **Beng Wah Ang and Tian Goh (2016), Carbon Intensity of Electricity in ASEAN: Drivers, Performance and Outlook.** ***Energy Policy, Volume 98, Pages 170-179.***

Abstract:

The Association of Southeast Asian Nations (ASEAN), with its ten member countries, has a total population exceeding 600 million. Its energy-related CO2 emissions have been growing and in 2013 amounted to 3.6% of total global emissions. About 40% of ASEAN's energy-related CO2 emissions are currently attributable to electricity production. In view of this high share, we study the CO2 emissions of ASEAN's electricity production sector with a focus on the aggregate emission intensity (ACI) given by the level of CO2 emissions for each unit of electricity produced. Drivers of ACI are analysed for individual countries and spatial analysis is conducted by comparing factors contributing to differences between the ACIs of individual countries and that of the ASEAN average. Arising from these analyses and in light of the current developments, it is concluded that drastic actions need to be taken both at the national and regional levels in order to reduce growth in the region's electricity-related CO2 emissions. Two key policy issues, namely overcoming national circumstances to improve electricity generation mix and improving power generation efficiency, are further discussed.

Published Technical Papers (with Abstracts)

7. Yi Tao, Ek Peng Chew, Loo Hay Lee, and Yuran Shi (2016), A Column Generation Approach for The Route Planning Problem in Fourth Party Logistics. ***Journal of the Operational Research Society.***

Abstract:

In this paper, we address the route planning problem in fourth party logistics (4PL). The problem calls for the selection of the logistics companies by a 4PL provider to optimize the routes of delivering goods through a transportation network. The concept of 4PL emerged in response to the shortfall in services capabilities of traditional third party logistics and has been proven to be capable of integrating logistics resources in order to fulfill complex transportation demands. A mixed-integer programming model is established for the planning problem with setup cost and edge cost discount policies which are commonly seen in practice. We propose a column generation approach combined with graph search heuristic to efficiently solve the problem. The good performance in terms of the solution quality and computational efficiency of our approach is shown through extensive numerical experiments on various scales of test instances. Impacts of cost policies on routing decision are also investigated and managerial insights are drawn.

Conference Papers (with Abstracts)

1. **Ghim Ping Ong and Weng Sut Sou (2016), An Integrative Economic-Transport Model Framework for Global Maritime Commodity Flow.** ***In proceeding of 19th Annual Conference on Global Economic Analysis, 15-17 June, Washington, USA.***

Abstract:

Maritime trade is the backbone of international trade and the global economy. It is of interest to policy-makers and planners to be able to properly forecast the amount of maritime commodity flow between countries (in terms of monetary value and physical volume) for policy making and infrastructure development. Numerous efforts have been made in the past to forecast maritime demand but most of these studies were either adopting an economic approach or a transportation model. Few studies actually consider the forecasting of maritime demand from an integrative economic trade-transportation modelling perspective. This paper presents the development of a quantitative demand forecasting approach to predict global maritime demand and commodity flow. This integrated forecasting framework uses the transportation-based four-step model coupled with economic and trade theories. Computable general equilibrium models based on economic theories are first developed to derive the amount of trade between countries. Through the application of transport mode choice models, the amount of seaborne trade between countries can be estimated. Statistical models are then developed to convert commodity value into number of containers or volume. The developed model framework are then applied to study global maritime trade trends with a focus on maritime trade in the Asia-Pacific region. It is demonstrated through the case studies presented in the paper that the ability of the model to forecast maritime trade and the capability of the developed model to evaluate the impact of trade policies on maritime trade.

2. **Yuquan Du, Qiang Meng, and Yadong Wang (2016). Artificial Neural Network Models for Ship Fuel Efficiency with Applications to In-Service Ship Fuel Consumption management.** ***In proceedings of 6th International Conference on Logistics and Maritime Systems, 21-23 June, Sydney, Australia.***

Abstract:

Many factors (sailing speed, cargo load, weather/sea conditions) in practice determines the fuel consumption rate (metric ton per day) of a ship at sea. However, their synergetic influence on ship fuel efficiency are not clearly addressed by existing studies from a quantitative viewpoint. Starting from a two-step procedure for ship fuel efficiency prediction, this paper proposes three possible models for a ship's bunker fuel efficiency based on artificial neural network (ANN) techniques. With the real shipping log data from a liner shipping company, the fitting performance of these three models are evaluated and compared over three 6600-TEU containerships. Experimental results reveal that the simplest model provides, nevertheless, the best fitting performance, thus becoming the suggested ship fuel efficiency model of this study. Our deep insights into shipping log data and engine shop test data also reveal the reasons why the other two models fail to present competitive fitting performance. Next, we move further beyond the technical aspects of the model, investigate its possible application from the managerial viewpoint, and propose a practical in-service bunker fuel management scheme for containerships. This scheme monitors a ship's fuel efficiency with a control chart containing control limits of its bunker fuel efficiency over each sailing leg. Once abnormality is detected, the suggested ANN model is triggered to conduct what-if analysis, which will quantitatively break down the contributions of serval determinants to this abnormality. This study represents our recent efforts with our industrial collaborator on data-driven methodology development for green shipping.

Conference Papers (with Abstracts)

3. **Yadong Wang and Qiang Meng (2016). Bunkering Problem with Bunker Price Uncertainty.** ***In proceedings of The Sixth International Conference on Transportation and Logistics, 7-9, September, Taiwan.***

Abstract:

This paper tactically designs bunker refueling strategy under uncertain bunker price so as to minimize the total shipping operation cost of a liner shipping company including bunker purchase cost and container ship operation cost. The bunker refueling strategy includes bunkering port selection and bunkering amount determination on the container ship voyages as well as container ship sailing speed in a shipping network operated by a liner shipping company. The bunker prices at bunker ports in the shippig network are assumed to have an unknown joint probability distribution but the descriptive statistics information i.e., the support (lower and upper bound), mean and variance are available from historical data. To solve this problem, a distributionally robust optimization method is adopted to deal with the uncertainty of bunker prices and formulate this problem as a mixed integer second order cone programming (MISOCP) model which can be efficiently solved. A numerical example based on a real-case liner shipping network from a global shipping company shows that proposed model is able to simultaneously control the average bunker purchase cost as well as the risk resulting from extremely high bunker price. Managerial insights are also given in the numerical example.

4. **Miyoung Han, Pierre Senellart, Stéphane Bressan and Huayu Wu (2016), Routing an Autonomous Taxi with Reinforcement Learning. In Proceedings of the 25th ACM International Conference on Information and Knowledge Management (CIKM), 24-28 October, Indianapolis, USA.**

Abstract:

Singapore's vision of a Smart Nation encompasses the development of effective and efficient means of transportation. The government's target is to leverage new technologies to create services for a demand-driven intelligent transportation model including personal vehicles, public transport, and taxis. Singapore's government is strongly encouraging and supporting research and development of technologies for autonomous vehicles in general and autonomous taxis in particular. The design and implementation of intelligent routing algorithms is one of the keys to the deployment of autonomous taxis. In this paper we demonstrate that a reinforcement learning algorithm of the Q -learning family, based on a customized exploration and exploitation strategy, is able to learn optimal actions for the routing autonomous taxis in a real scenario at the scale of the city of Singapore with pick-up and drop-off events for a fleet of one thousand taxis.

CMS Research Seminars

1. **Python Language for High Performance Scientific Computing, by Researcher Dr. Zhang Liye (Track Leader: Professor Meng Qiang)**

   Seminar Abstract:

   Python programming language is widely used in both academic community and industry filed. It is an object-oriented language, which is easy to learn and has large number of libraries for scientific computing. However, as a dynamic language the performance is one big problem for many CPU-intensive tasks. In this presentation, I will firstly give a briefly introduction of Python programming for statistical analysis and optimization calculation (mathematical programming). Then, the technologies for high performance of Python programming are presented, including language implementation with JIT technologies (eg. Pyston and PyPy), JIT technologies during running time, parallel computing technologies, vectorization programming and python extension using C++ language. These technologies are illustrated with small and simple examples as easy as possible.

2. **Artificial Neural Network Models for Ship Fuel Efficiency with Applications to In-Service Ship Fuel Consumption Management, by Researcher Dr. Du Yuquan (Track Leader: Professor Meng Qiang)**

   Seminar Abstract:

   Many factors (sailing speed, cargo load, weather/sea conditions) in practice determines the fuel consumption rate (metric ton per day) of a ship at sea. However, their synergetic influence on ship fuel efficiency has not been clearly addressed by existing studies from a quantitative viewpoint. Starting from a two-step procedure for ship fuel efficiency estimation, this paper proposes three possible models for a ship's bunker fuel efficiency based on artificial neural network (ANN) techniques. With the real shipping log data from a liner shipping company, the fitting performance of these three models are evaluated and compared over three 6600-TEU containerships. Experimental results reveal that the simplest model provides, nevertheless, the best fitting performance, thus becoming the suggested ship fuel efficiency model of this study. Our deep insights into shipping log data and engine shop test data also reveal the reasons why the other two models fail to present competitive fitting performance. Next, we move further beyond the technical aspects of the model, investigate its possible application from the managerial viewpoint, and propose a practical in-service bunker fuel management scheme for containerships. This scheme monitors a ship's fuel efficiency with a control chart containing control limits of its bunker fuel efficiency over each sailing leg. Once abnormality is detected, the suggested ANN model is triggered to conduct what-if analysis, which will quantitatively break down the contributions of serval determinants to this abnormality. This study represents our recent efforts with our industrial collaborator on data-driven methodology development for green shipping.

3. **Ocean Wave Simulation and Its Effect to Floating Structure , by Researcher Dr. Yang Jiasheng (Track Leader: Professor Fwa Tien Fang)**

   Seminar Abstract:

   Ocean surface wave is regarded as the main uncertain factor to affect the performance of ships in the ocean. In order to effectively perform maritime studies, it is of great importance for researchers to understand the characteristics of ocean wave and its effect to ship performance. In this presentation, we introduce the principle of ocean waves, and analyse the mathematical description of ocean wave. Furthermore, several examples are given to illustrate how the ocean wave affects the performance of ships. It is expected that this presentation could enrich our knowledge about ocean surface wave effects.

CMS Research Seminars

4. Liner Container Shipping Demand Forecasting for Intercontinental Shipping Service, by Researcher Mr. Wang Yadong (Track Leader: Professor Meng Qiang)

Seminar Abstract:

Liner shipping links trades between different continents in the international logistic system. This paper investigates how to forecast the realized container shipping demand before each ship voyage for the long haul leg of intercontinental shipping service based on currently arrived container slot booking data during booking period. As container shipping demand across the long haul leg significantly affects profitability of the whole service, it is a very important input for tactical and operational shipping service planning. In this paper, a novel integrated forecasting model with a self-adaptive weight average method is developed. This model is able to combine the predictions from different forecasting models such as piecewise liner regression model, autoregressive model and artificial neural network model by assigning weights to these models and work in a rolling horizon manner by dynamically adjusting their weights to reflect new trend for container shipping demand. Test results on real container slot booking data from several intercontinental services shows high forecasting precision of this model. Some applications of this demand forecasting in intercontinental service planning are also briefly introduced.

5. Assessment of Different Genetic Algorithms for Pavement Management Systems, by Researcher Mr. André V. Moreira (Track Leader: Professor Fwa Tien Fang)

Seminar Abstract:

As road administrations keep seeking for innovative ways to improve the means to manage their road assets, the continuous progresses of Pavement Management Systems (PMSs) towards a consistent and effective utility play an important role. An optimization methodology to support decision making is a key aspect of any PMS. In this paper, two genetic algorithms based optimization approaches are addressed. One comprises a multi-objective solver which uses the non-dominated sorting genetic algorithm II (NSGA-II). The other consists in using a genetic algorithm to optimize a single-objective function that is obtained after combining together the multiple objectives through the augmented Tchebycheff method with infinite norm. Objective functions and constraints are related with the pavement quality over time and the total costs of maintenance and rehabilitation (M&R) strategies. For each algorithm, three different constraint handling methods are analysed and compared; (1) a posteriori implementation; (2) constraint function; (3) penalty function. The results showed that, regardless specific modifications to the default algorithms' options, the multi-objective solver with a posteriori constraints or with a penalty function are the approaches more likely to provide the best approximations to the optimal solutions.

6. Stated Preference and Survey Design, by Researcher Ms. Zhang Yiru (Track Leader: Professor Meng Qiang)

Seminar Abstract:

The viability of the Northern Sea Route (NSR) can be understood from navigation and commercial perspectives. Based on existing studies, researchers expected the NSR to become an attractive alternative to existing shipping routes. However, the real ship traffic at NSR demonstrates a different picture. In our project, the impact of opening of the NSR on the port of Singapore would be analyzed by quantifying the shift in shipping market share from traditional shipping routes to transarctic routes. The changes in shipping market share can be estimated by using discrete choice models. We believe that it is important to understand shipping companies' perspectives in order to have accurate model calibration. However, since the NSR is an emerging route and few companies have indeed travelled via the route, we do not observe the decision making of companies so far. Hence, a stated preference research with carefully designed survey is required for data collection. In this seminar, we introduced the basic theories behind and illustrate our survey questions.

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7. Estimation for Commuters' Value-Of-Time Distribution in Singapore, by Researcher Ms. Lu Zhaoyang (Track Leader: Professor Meng Qiang)

Seminar Abstract:

To cope with deteriorated traffic congestion, the government of Singapore has implemented some transport policies for demand management, including the Certificate of Entitlement (COE), Vehicle Registration Charge, Electronic Road Pricing (ERP), among others. These policies all take the economic level to affect the commuters travel behaviors. Studies of these policies are confronted by two travel cost components: travel time and out-of-pocket money. To make these two components commeasurable for analysis, the Value of Time (VOT) is of high importance. In practice, the commuters' VOT is largely affected by their level of income and trip emergency, making the individual VOT value quite different. Thus, instead of using constant/mean values, a continuously distributed term should be adopted for VOT, to cover its diversity among the whole population. Based on first-hand field survey data from SP hybrid survey method, the VOT of low and middle income level commuters can be estimated by NL models and the highway income commuters by MNL discrete models. With the aid of some software, we get the calibration the continuous VOT distributions in Singapore. Apart from the distribution function, this paper also updates the mean VOT value which is S$ 29.54/h in average.

8. An ANN Model to Correlate Roughness and Structural Performance in Asphalt Pavements, by Researcher Mr. Giuseppe Sollazzo (Track Leader: Professor Fwa Tien Fang)

Seminar Abstract:

Pavement surface must provide a high standard of quality in terms of structural and functional performance to ensure comfort and safety while driving. Road agencies have to continuously conduct surveys to monitor the pavement quality and perform maintenance operations to maintain adequate driving conditions. Most highway agencies do not conduct structural surveys as regularly as functional surveys because the former are costly, time consuming, and disruptive to traffic. It is of practical significance if the structural state of a pavement can be estimated from its functional conditions. Even though this connection is obvious from a theoretical point of view, any relevant mathematical relationship to correlate them has not been produced so far. Using a large database from the Long Term Pavement Performance program, an Artificial Neural Network (ANN) to estimate the structural performance (as effective Structural Number - SNeff) of asphalt pavements from roughness data (evaluated in terms of International Roughness Index - IRI) has been developed. To characterize different scenarios, various input parameters have been included in the analysis, such as traffic, weather, and structural variables. The results are very interesting and prove that the ANN represents an adequate model to evidence it. This approach demonstrated with good accuracy a significant relationship between IRI and SNeff.

9. Understanding the Maritime Traffic Behavior – Factors Affecting the Critical Ship Safety Distance (2), by Researcher Dr. Zhang Liye (Track Leader: Professor Meng Qiang)

Seminar Abstract:

Understanding the maritime traffic behavior is critical for ship traffic simulation and safety analysis. Critical ship safety Distance (CSSD) is a concept which reflects the captain's decision-making during navigation. This paper aims to investigate factors affecting the CSSD based on the field data analysis. First, we select the candidate factors by quantitative analysis from the perspective of ship movement mechanism. To consider the effect of water depth and ship draft, we proposed a concept of Valid Navigation Space (VNS). Moreover, we also take into account of the rate of course, which is related to navigation risk. Then, we use the FAMD model (factor analysis of mixed data) to investigate the significant impact factors for CSSD and the relationship between the factors.

In this paper, the candidate factors include relative ship speed, the angle between the courses of two ships, ship tonnage, visualization, ship age, ship flag state, the rate of course and VNS. The FAMD model is conducted using

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the AIS data in a fairway in Singapore of one month. The results show that VNS, relative ship speed, the angle between the courses of two ships, and the ship tonnage are the top four most important factors for CSSD.

10. 6DOF Ship Motion Simulator Development: Concept Design, by Researcher Dr. Yang Jiasheng (Track Leader: Professor Fwa Tien Fang)

Seminar Abstract:

Nowadays, some advanced measurement systems have been developed to install on-board to capture the more reliable data for ship performance analysis. In order to assess and improve the accuracy of these measurement systems before installation, it is of great value to develop a 6DOF ship motion simulator to calibrate and validate the measurement systems. In this presentation, we introduce the initial concept design of 6DOF ship motion simulator. First, we introduce the development of ship dynamics model. Then, we further introduce the development of 6DOF motion platform. It is expected that the proposed concept design is sufficient to develop a ship dynamic platform for measurement system calibration.

11. Liner Shipping Bunkering Problem with Bunker Price Uncertainty, by Researcher Mr. Wang Yadong (Track Leader: Professor Meng Qiang)

Seminar Abstract:

This study tactically designs bunker refueling strategy under uncertain bunker price so as to minimize the total shipping operation cost of a liner shipping company including bunker purchase cost and container ship operation cost. The bunker refueling strategy includes bunkering port selection and bunkering amount determination on the container ship voyages as well as container ship sailing speed in a shipping network operated by a liner shipping company. The bunker prices at bunker ports in the shippig network are assumed to have an unknown joint probability distribution but the descriptive statistics information i.e., the support (lower and upper bound), mean and variance are available from historical data. To solve this problem, a distributionally robust optimization method is adopted to deal with the uncertainty of bunker prices and formulate this problem as a mixed integer second order cone programming (MISOCP) model which can be efficiently solved. A numerical example based on a real-case liner shipping network from a global shipping company shows that proposed model is able to simultaneously control the average bunker purchase cost as well as the risk resulting from extremely high bunker price. Managerial insights are also given in the numerical example.

12. Marine Traffic Simulation Model Based on Multi-agent in Singapore Straits, by Researcher Dr. Xie Yajuan (Track Leader: Professor Meng Qiang)

Seminar Abstract:

For the purpose of re-configuration or re-design of marine traffic system, Marine Traffic Simulation Model based on multi-agent in Singapore Straits was developed. This is a tool to evaluate marine traffic for the re-construction or configuration in Singapore Straits. It includes the modeling for human behavior, ship generator, route choice, navigation modes, including crossing, head-on and following scenarios, collision avoidance rules, risk assessment. It will be easily evaluated using this simulation model how much degree the safety will change according to the change of traffic conditions such as traffic quantity, navigational area etc.

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13. Modeling and Solving the First Train Timetabling Problem with Minimal Missed Trains in Subway Networks, by Researcher Dr. Kang Liujiang (Track Leader: Professor Meng Qiang)

Seminar Abstract:

Urban railway transportation organization is a systematic activity that is usually composed of several stages, including network design, line planning, timetabling, rolling stock and staffing. In this paper, we study the optimization of first train timetables for an urban railway network that focuses on designing convenient and smooth timetables for morning passengers. We propose a mixed integer programming (MIP) model for minimizing train arrival time differences and the number of missed trains, i.e., the number of trains without transfers within a reasonable time at interchange stations as an alternative to minimize passenger transfer waiting times. This is interesting from the operator's point of view, and we show that both criteria are equivalent. Starting from an intuitive model for the first train transfer problem, we then linearize the non-linear constraints by utilizing problem specific knowledge. In addition, a local search algorithm is developed to solve the timetabling problem. Through computational experiments involving the Beijing subway system, we demonstrate the computational efficiency of the exact model and the heuristic approach. Finally, three practical suggestions are proposed for the operation and management of the urban railway transit system.

