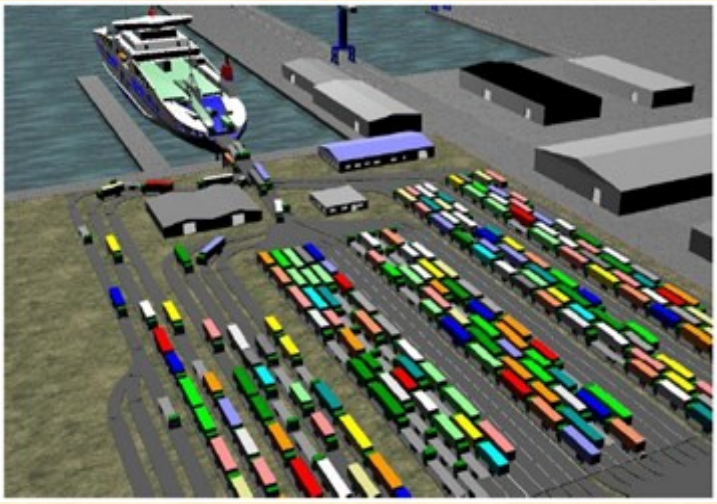
Research Highlight 1: eTSSO: Adaptive Search Method for Stochastic Global Optimization Under Finite Budget, By Dr. Giulia Pedrielli (Track Leader: Assoc/Prof. Ng Szu Hui)

MOTIVATION

Computer models are widely used to simulate physical systems (e.g., container terminals, ocean liner shipping networks, complex supply chains). Most of the times simulation is coupled with a search algorithm to support decision makers. However, models are usually expensive to run, hence, the optimization technique has to be efficient enough to require the least number of simulation experiments.

In this research, we propose an efficient search algorithm that tries to maximize the use of the information coming from each simulation in order to solve a stochastic optimization problem given a fixed simulation budget.



PROBLEM DESCRIPTION

TSSO is a recently proposed search algorithm based on the Modified Nugget Effect Kriging (MNEK) meta-model, and solves unconstrained stochastic simulation optimization problems with heterogeneous variances, when the total simulation budget is fixed, through a budget allocation followed by a two–stage sequential procedure. Specifically, a typical unconstrained optimization problem can be modeled as:

$$\mathrm{P}: \min y(x)$$
$$\text{s.to} \quad x \in X$$

X is a compact set representing the domain of the function y which is a deterministic

d – dimensional function defined as. In our problem, the function y can only be measured with noise running a complex simulation model.

Two families of approaches can be identified to solve the problem through the joint use of simulation and optimization (both deterministic and stochastic settings): (1) Direct methods: the simulator is called at each iteration to obtain an estimate of the response; (2) Surrogate methods: use simulation to estimate the corresponding meta–model which guides the search. In this second category, which is of interest in this work, kriging metamodels resulted particularly successful as meta-model forms.

CONTRIBUTIONS

C1: We study the structural properties of the TSSO algorithm delving into the analysis of its asymptotic behavior. The formal analysis is provided for the one–dimensional case and empirical evidence of the asymptotic behavior is also provided for higher dimensions.

C2: we improve the TSSO algorithm performance. In fact, TSSO performance are quite influenced by the decision on the number of simulation replications allocated to each iteration (B) given the total available budget T, i.e., to the pair (T;B). We propose a new adaptive budget allocation scheme which mitigates the effect of the initial TSSO settings and avoids the user to choose an appropriate value of B.

MNEK Model

In particular we use the MNEK model as Kriging meta-model of the simulation response:

$$Y(x_i) = Z(x_i) + \xi(x_i) \qquad i = 1,\ldots,k, Z(x_i) \sim GP(\mu, \tau^2 R_z)$$

Kriging model with non-homogeneous variance

$$R_z\left(Z(x_i), Z(x_j)\right) = \prod_{l=1}^{d} \exp\left(-\phi_{z,l}\left(x_{il} - x_{jl}\right)^2\right), \quad \xi(x_i) \sim N\left(0, \sigma_\xi^2(x) R_\xi\right)$$

Correlation Model

Research Highlight 1: eTSSO: Adaptive Search Method for Stochastic Global Optimization Under Finite Budget, By Dr. Giulia Pedrielli (Track Leader: Assoc/Prof. Ng Szu Hui)

MNEK Model

The TSSO algorithm uses the MNEK as foundation and selects as potential solution(s) those points in the space X which maximizes the Modified Expected Improvement (MEI) function:

$$x_k \in \arg\max_{x\in X, x\notin \mathrm{S}} \left(T_k(x)\right) = \arg\max_{x\in X, x\notin \mathrm{S}} E\left(\max\left\{y^*_{k-1} - \hat{Y}_k(x), 0\right\}\right)$$

Compare the best sampled function value up to iteration k (i.e., y^*_{k-1}) with the kriging forecast (i.e., $\hat{Y}_k(x)$) at the un-sampled points ($x \notin \mathrm{S}$).

TSSO Overview

At the first stage, for the search, TSSO uses the MNEK model to explore the region and to define new candidate solutions. The evaluation stage runs simulation experiments at each point according to the Optimal Computing Budget Allocation (OCBA) rule and the Kriging model is subsequently updated.

ASYMPTOTIC CONVERGENCE ANALYSIS

To study the TSSO convergence we refer to this version of the algorithm, which we call.

ALGORITHM 2: Sequential TSSO algorithm with budget increase and uniform sampling (1–d case)

Initialization: $k = 0$;
Define the N_0 space filling design, the initial available budget B_0, the replication increase coefficient Δ^B. Fit the MNEK model response model to the set of sample means;
Cross validate to check if the initial model fit is satisfactory.
$k = N_0$.
Do Choose the new point $x_k \notin \mathbb{S}$ solving: $x_k \in \arg\max_{x\in\mathbb{X}} T_k(x; D_k)$;
Reorder the set of sampled locations $\mathbb{S}$:
if $\exists i,\ 2 \le i \le k:\ x_k \in (x_{i-1}, x_i)$ **then**
    set $x_k \leftarrow x_i$ and $\forall j \ge i : x_j \leftarrow x_{j+1}$ and $x \leftarrow x_j$
end
else
    $x_k \leftarrow x_1$ and $\forall j \ge 1 : x_j \leftarrow x_{j+1}$
end
Assign to the new point a number of replications $n_i = r_{min}$;
Increase the number of replications according to $B_k = B_{k-1} + \Delta^B \cdot (k)^2$;
Allocate to each sampled point a number of replications $n_k = \lfloor \frac{B_k}{k} \rfloor$;
$k = k + 1$;
Fit the MNEK model according to the updated information.

Assumption 1: the function to be optimized is a 1-d function. The parameters of the MNEK model are known (ϕ_z, τ^2).

Assumption 2: The number of simulation replications increases at each iteration and the available replications per iteration are uniformly allocated among the sampled points.

Assumption 3: The Gaussian correlation function modelling the process correlation is chosen from the exponential family form.

Research Highlight 1: eTSSO: Adaptive Search Method for Stochastic Global Optimization Under Finite Budget, By Dr. Giulia Pedrielli (Track Leader: Assoc/Prof. Ng Szu Hui)

ASYMPTOTIC CONVERGENCE ANALYSIS

Lemma 1: As the number of iterations $k \to \infty$, under Assumptions 1 and 2, the MNEK model approaches its deterministic counterpart.

Lemma 2: As the number of iterations $k \to \infty$, $\hat{Y}(x \mid D_k) \sim N\left(\mu_{|D_k}, \sigma^2_{|D_k}(x)\right)$ D_k, the information Available at iteration k.

Property 1: The function $T_k(x)$ is Lipschitz continuous over its support.

Theorem 1: $TSSO_U^{\Delta B}$ ***uniformly converges to the global optimum.***

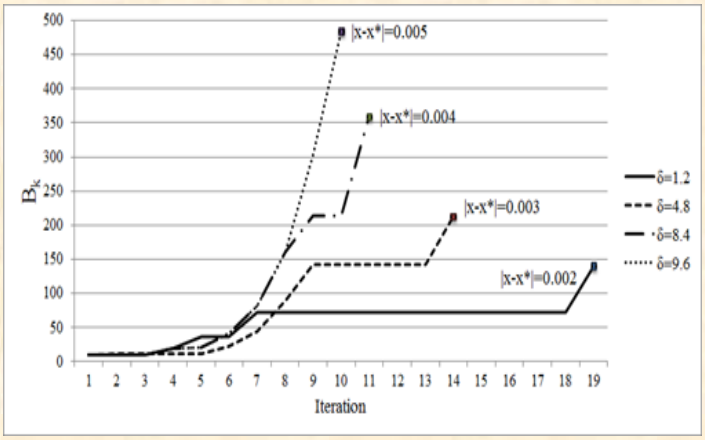
We created $TSSO_{OCBA}^{\Delta B}$ which is as TSSO but, as $TSSO_U^{\Delta B}$, increases the number of replications by a *constant predefined* rate Δ_B. The budget increase has the positive effect to decrease the influence of the budget per iteration B. The performance of $TSSO_{OCBA}^{\Delta B}$ are highly dependent on Δ_B .BUT Selecting Δ_B is not a trivial task.

ETSSO ALGORITHM

IETSSO Algorithm improves TSSO through a rule that adaptively sets Δ_B in order to balance the need to reduce the noise (larger values of Δ_B) and the need to have enough iterations to explore the design (small Δ_B). The new scheme for increasing the number of simulation replications at each iteration is:

$$B_k = \left\lfloor B_{k-1}\left(1 + \frac{\hat{\sigma}^2_{\xi,k}}{\hat{\sigma}^2_{\xi,k} + s^2_{z,k}}\right)\right\rfloor$$

The budget is increased according to the ratio between the noise variance $\hat{\sigma}^2_{\xi,k}$ and the total response variance $\left(\hat{\sigma}^2_{\xi,k} + s^2_{z,k}\right)$, i.e., noise variance plus process variance.



When $\hat{\sigma}^2_{\xi,k}$ is low, or we are at the beginning of the search, the increase rate is low. In case the noise is large or the search is at the final stages (the $s^2_{z,k}$ should be lower) the rate increases: this is positive for the case of large variance as with more replications the quality of the estimation increases.

Research Highlight 1: eTSSO: Adaptive Search Method for Stochastic Global Optimization Under Finite Budget, By Dr. Giulia Pedrielli (Track Leader: Assoc/Prof. Ng Szu Hui)

Numerical Comparison between eTSSO and Genetic Algorithm

Tetramodal function:

$$Y(x_1,x_2) = -5\left(1-(2x-1)^2\right)\left(1-(2x_2-1)^2\right)(4+2x_1-1)\left(0.05^{(2x_1-1)^2} - 0.05^{(2x_2-1)^2}\right)^2$$

Table IV. Results for the Tetramodal function

Algorithm	δ	$\lvert x-x^*\rvert$		$\lvert y-y^*\rvert$	
		average	std err	average	std err
eTSSO	0.6	0.0054	0.0038	0.0331	0.0301
	1.2	0.0072	0.005	0.0462	0.0405
	2.4	0.0072	0.0047	0.061	0.0476
	3.6	0.01	0.0069	0.0746	0.0622
	4.8	0.0094	0.007	0.087	0.0791
	9.6	0.014	0.0096	0.1512	0.1258
GA	0.6	0.2714	0.223	1.3979	1.15
	1.2	0.3421	0.2212	1.1702	0.8644
	2.4	0.2648	0.237	1.0001	0.8174
	3.6	0.2987	0.2358	1.1784	0.9165
	4.8	0.2861	0.2357	0.9942	0.6865
	9.6	0.3078	0.2383	0.9529	0.725

The performance of the algorithm are affected by the noise variance especially in the response estimation. eTSSO is always better than the Genetic Algorithm over all the test functions.

In fact GA cannot converge to the global optimum in most of the replications. This behavior can be brought back to the multi modal nature of the functions under analysis.

Conclusions & Future Research

We proved the convergence for a simplified version of TSSO, where the number of simulation replications is increased at each iteration. We show empirically that the restrictions made do not influence the algorithm convergence. The budget increase reveals positive effects on the algorithm performance especially when high noise affects the function, but, the budget increase rate is difficult to size. We then propose eTSSO, which, through a new allocation approach, adaptively increases the simulation budget at each iteration without the need to define the budget increase rate as input information. Results were compared with the original TSSO and with the GA and both were promising. Further research is being developed to extend the comparison study and improve the search criterion of the algorithm.

Acknowledgments

This research was supported in part by the research project grant (R-SMI-2013-MA-11) funded by the Singapore Maritime Institute.

Research Highlight 2: Impacts of IMO Technical and Operations Energy Efficiency Measures on Singapore Registered Ships, By Ms Sou Weng Sut, Maggie (Track Leaders: Prof Fwa Tien Fang, Prof Ang Beng Wah, Assoc/Prof Chai Kah Hin and Assoc/Prof Ng Szu Hui)

Objective

The objectives of this study are to examine the applicability of the IMO technical and operational measures for improving the energy efficiency of Singapore-registered ships by studying the potential energy efficiency gain and cost-effectiveness from each of these technical and operational measures on Singapore-registered ships.

Acknowledgement

The authors would like to thank the Singapore Shipping Association for active participation in the questionnaire surveys. We also want to show our sincere thanks to Mr Goh Hung Song and Captain Tey Yoh Huat for their valuable advice along this study.

Background

Presently, 90% of the global merchandise trade is conducted by global shipping. In 2007, 870 million tonnes of CO2 were emitted from international shipping, contributing 2.7% of the total global CO2 emissions. With sustained growth in shipping, maritime CO2 emissions are projected to increase by two to threefold by the year 2050.

Citing this significance growth greenhouse gas (GHG) emission, IMO has initiated a series of studies starting from 1997, in which the Marine Environment Protection Committee (MEPC) was invited; to consider what CO2 reduction strategies might be feasible to be applied in the shipping industry. However, all these studies investigated the global fleet as a whole but did not provide any advice to regional authorities about ships under their own flags.

In view of this, this study aims to address the impacts of the proposed IMO technical and operational energy efficiency measures on various categories of cargo-carrying ships under the Singapore's registration.

Methodology

This study consists of mainly three parts, i.e. statistical analysis on Singapore-registered ships for understanding the current profile of existing ships and the growth of Singapore fleet over the years, questionnaire survey for industry experts to collect related fuel-efficiency improvement data and cost from their current practice, and cost-effectiveness calculations on individual energy-efficiency measures and the marginal abatement cost (MAC) calculations for the Singapore fleet.

(1) Statistical analysis on Singapore-registered ships

Based on the Singapore-registered ship data collected from public sources and other databases, the changes in the profile of Singapore fleet between 2007 and 2013 could be explored, thus providing a background and distinct properties of Singapore fleet. Besides, the existing Singapore's ship profile was also compared against with the global fleet so as to recognise the weakness and strength of Singapore fleet in the world.

(2) Quantitative survey on Singapore-based shipping companies

A questionnaire survey, in collaboration with Singapore Shipping Association (SSA) has been conducted on Singapore-based shipping companies which own and operate bulk carriers, tankers and containerships. This survey aimed to collect data relating to fuel-efficiency improvement data and cost from industry experts.

Research Highlight 2: Impacts of IMO Technical and Operations Energy Efficiency Measures on Singapore Registered Ships, By Ms Sou Weng Sut, Maggie (Track Leaders: Prof Fwa Tien Fang, Prof Ang Beng Wah, Assoc/Prof Chai Kah Hin and Assoc/Prof Ng Szu Hui)

Methodology

(3) Cost-effectiveness (CE) analysis on individual operation and technical energy-efficiency measure

In examining the energy-efficiency improvement measures on different categories of ships, as shown in Table 1, a standardised methodology has been developed in several studies, thus it will be adopted in this project. This methodology is namely the MAC (or CE) analysis. The major task is to investigate the CE value of each measure as well as the potential total CO2 emission reduction from applying such measures. Then they are ranked from the least cost to the highest, and plotted into a graph, namely marginal abatement cost curve (MACC), for easy identification of the economic feasibility of each measure. Through discussions with shipping industry expertise and based on the information available for these measures, 14 operational and technical measures are shortlisted and examined in this study, as listed in Table 2.

Table 1 Category of Vessels Considered in this Study

	Vessel Types
1	Crude Oil Tanker
2	Product Tanker
3	Chemical Tanker
4	LPG Tanker
5	LNG Tanker
6	Container Ship
7	Bulk Carrier

Table 2 Operational and Technical Measures Considered in this Study

Technical and Operational Measures			
1	Air Lubrication	8	Propeller Boss Cap with Fins
2	Autopilot Adjustment	9	Propeller polishing (at regular intervals)
3	Hull coating I	10	Propeller Polishing when Required
4	Hull coating II	11	Propeller Upgrade
5	Integrated Propeller and Rudder Upgrade	12	Speed Control of Pumps and Fans
6	Main Engine Tuning	13	Speed Reduction
7	Optimization water flow of hull openings	14	Weather Routing

$$MAC = \frac{\Delta C_j}{\alpha_j \times CF \times F} \quad (1)$$

$$\Delta C_j = K_j + S_j - E_j + \sum O_j \quad (2)$$

$$E_j = \alpha_j \times F \times P \quad (3)$$

Cost-effectiveness is by definition the quotient of costs and effect. This is also referred to as marginal abatement costs (MAC) as defined in the MEPC 62 report.

Research Highlight 2: Impacts of IMO Technical and Operations Energy Efficiency Measures on Singapore Registered Ships, By Ms Sou Weng Sut, Maggie (Track Leaders: Prof Fwa Tien Fang, Prof Ang Beng Wah, Assoc/Prof Chai Kah Hin and Assoc/Prof Ng Szu Hui)

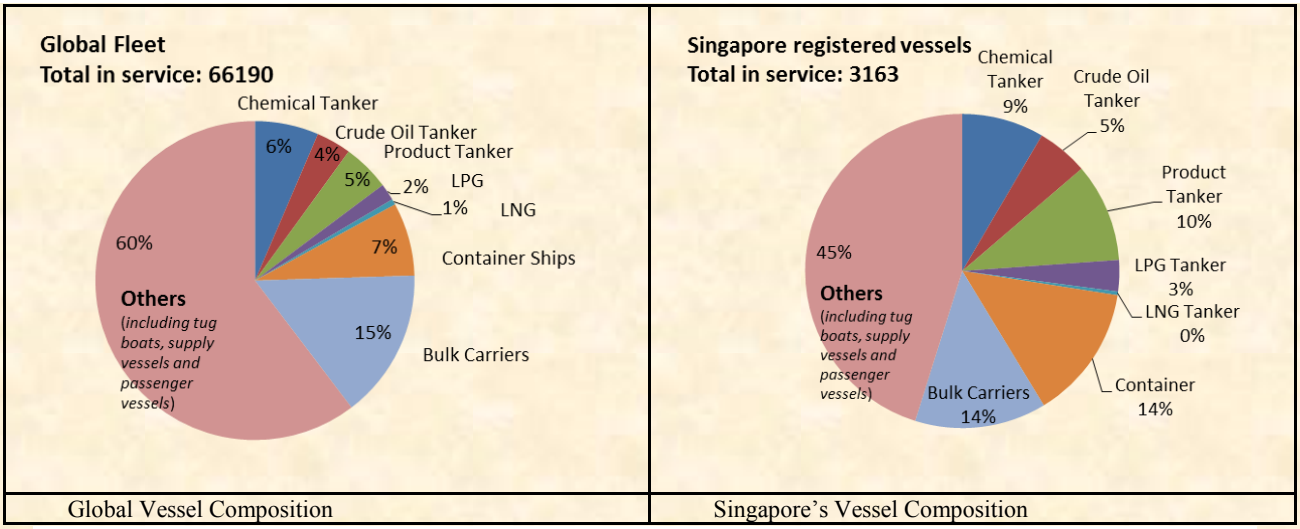
Methodology

where ΔCj is the additional annual cost for installing the technology/implementing the measure j, Kj is the annualized capital cost of implementing the measure (non-recurring cost spread over the life time of the measure), Sj is the operating cost/ recurring cost for the measure, Ej is the amount fuel expenditure savings from implementing the measure, which is a product of the abatement potential αj of the measure j, the fuel price P and fuel saving F, and Oj is the opportunity cost incurred while implementing the measure such as the extra dry docking and space used; CF is the carbon emission factor, i.e. the mass of CO2 emitted when a unit of mass of fuel is burned. In this study, the conversion factor used is 3.13 tons CO2/tons fuel.

Results and Discussion

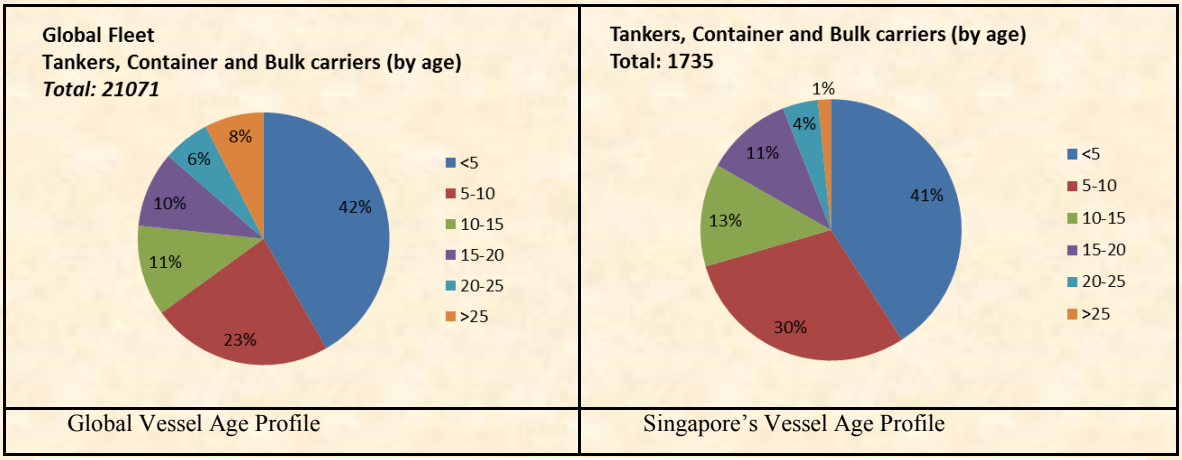
(1) Statistical analysis on Singapore-registered ships

From the analysis of profile of the Singapore-registered ships in 2013, it could be observed that over 70% of Singapore's ocean going fleet (i.e. tankers, container ships and bulk carriers) was less than age of 10 and the majority of vessels were small to mid-sized. When comparing to the global fleet on the age profile and also the fleet composition, Singapore fleet is considered to be younger and consists of more cargo-carrying vessels.



Global Vessel Composition | Singapore's Vessel Composition

Figure 3.7 Comparison in Vessel Composition between Global and Singapore's fleet in 2013



Global Vessel Age Profile | Singapore's Vessel Age Profile

Figure 3.8 Comparison in Age Profile between Global and Singapore's fleet in 2013

Research Highlight 2: Impacts of IMO Technical and Operations Energy Efficiency Measures on Singapore Registered Ships, By Ms Sou Weng Sut, Maggie (Track Leaders: Prof Fwa Tien Fang, Prof Ang Beng Wah, Assoc/Prof Chai Kah Hin and Assoc/Prof Ng Szu Hui)

Results and Discussion

(2) Quantitative survey on Singapore-based shipping companies

Based on the information collected from survey, Singapore-based shipping companies generally reported to achieve less than 5% fuel efficiency improvement between 2011 and 2013 except some best performing companies claimed to achieve 20% or more fuel savings. Slow steaming was ranked as the most fuel-efficient operational measure whereas optimising water flow of hull openings was ranked as the most fuel-efficient technical measure by the shipping companies. From the survey, it could be noted that these companies were appeared to be relatively conservative in further improving their ships' fuel efficiency in 2014 since majority of them targeting between 1 and 6% only.

(3) Cost-effectiveness (CE) analysis on individual operation and technical energy-efficiency measure

Finally, the cost effectiveness analysis examined both new and existing ships as projected in 2020. One significant finding was that the MACC for 2020 showed a considerable abatement potential at negative costs, meaning that many of these operational and technical measures were profitable on both new and existing ships. It could be seen that weather routing appeared to be the most cost effective measure in most case scenarios whereas main engine tuning appeared to be the least cost effective measure in most case scenarios. The potential reduction in CO2 emission from Singapore fleet in 2020 under various case scenarios ranged from 16.0 to 42.92 Mt, i.e. achieving 29.4% to 77.8% reduction in comparison to business-as-usual scenarios.

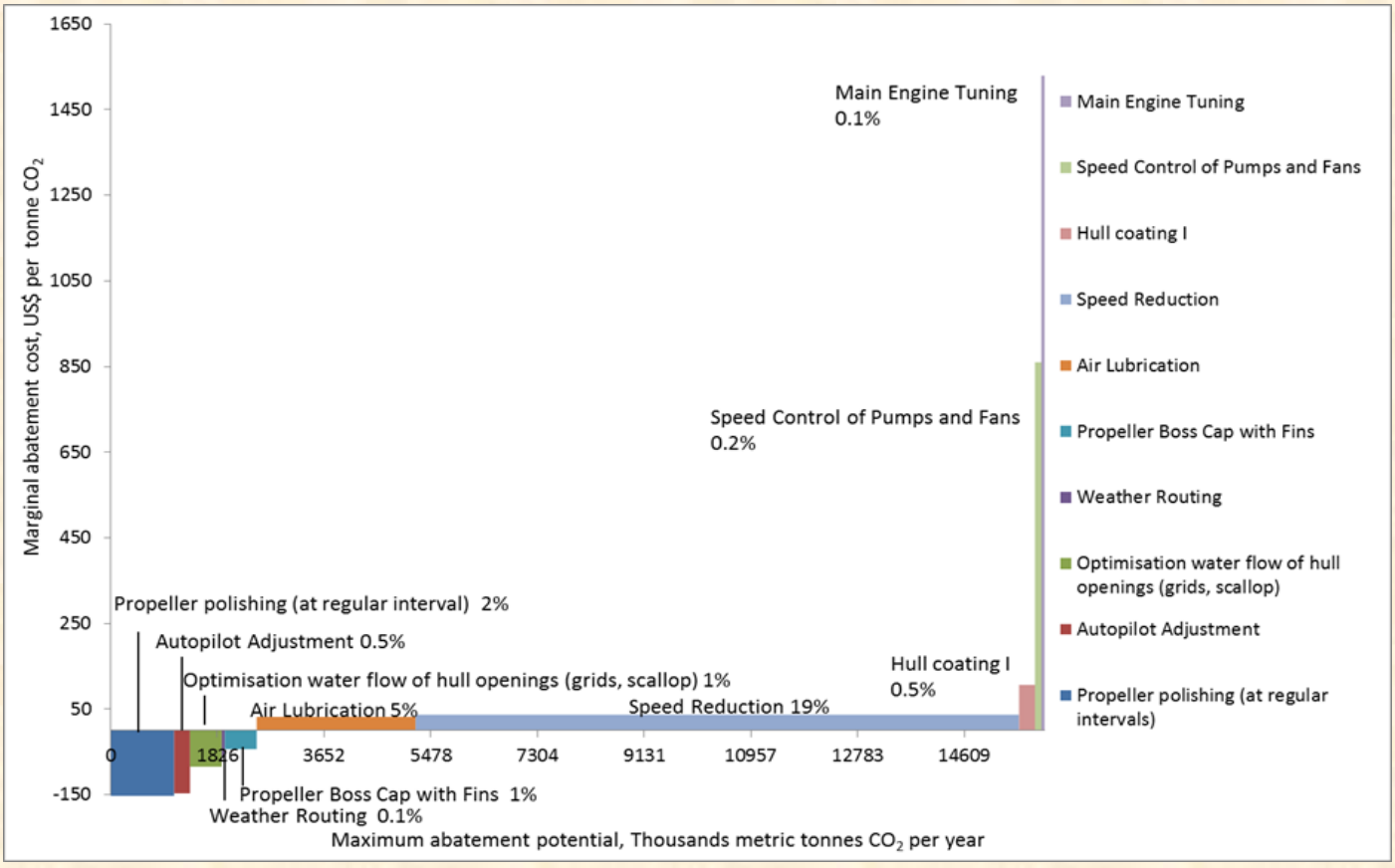


Figure 1 Aggregated MACC for Pessimistic Case in 2020

Research Highlight 2: Impacts of IMO Technical and Operations Energy Efficiency Measures on Singapore Registered Ships, By Ms Sou Weng Sut, Maggie (Track Leaders: Prof Fwa Tien Fang, Prof Ang Beng Wah, Assoc/Prof Chai Kah Hin and Assoc/Prof Ng Szu Hui)

Results and Discussion

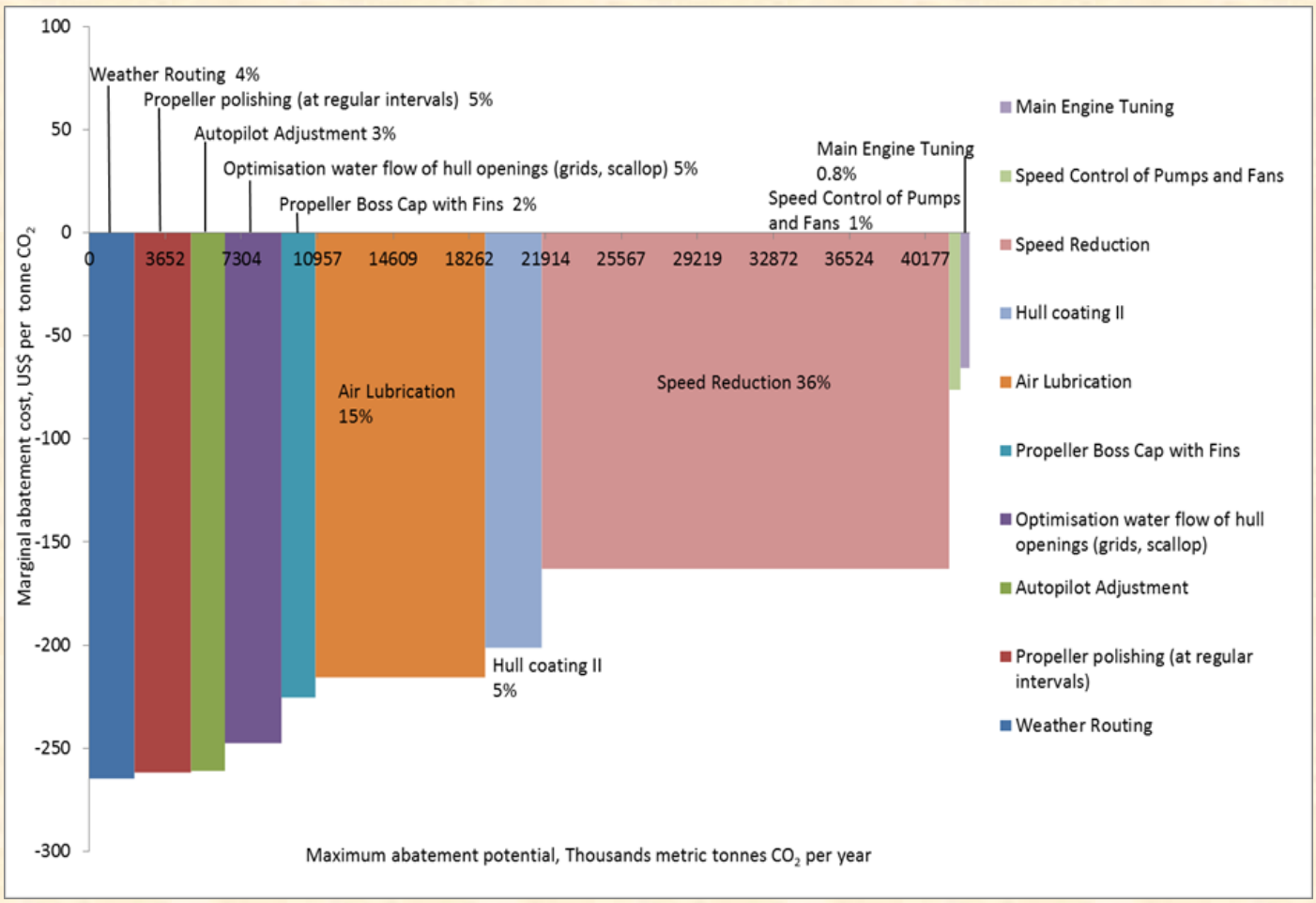


Figure 2 Aggregated MACC for Optimistic Case in 2020

Conclusion

This project could be claimed as the first study with combining efforts from both academic and industrial parties in evaluating the potential energy efficiency gain and cost-effectiveness from IMO technical and operational measures on Singapore-registered ships. Besides, with collaboration with SSA, industrial parties have also contributed in this study by providing their current stage in implementing energy-efficiency measures. This study hoped to present the first phase of a series of studies on shipping emissions and/or energy efficiency of Singapore registered ships.

Published Technical Papers (with Abstracts)

1. Wang Hua, Wang Shuaian and Meng Qiang, (2014), Simultaneous optimization of schedule coordination and cargo allocation for liner container shipping networks. *Transportation Research Part E*, 2014. 70(0): pp. 261-273

Abstract:

A liner container shipping carrier usually collects immediately-delivered goods that are produced by manufacturers in world factories, and transports the products to worldwide market destination by offering weekly shipping service. In practice, the carrier has to consider extra demurrage cost of containerized cargos incurred from waiting for weekly shipping service at ports. In this paper, we develop a mathematic programming model to maximize the carrier's profitability by simultaneously optimizing the ship route scheduling and interrelated cargo allocation scheme. The nonlinear optimization model is transformed into an equivalent mixed-integer linear program, and its applicability is demonstrated by a case study.

2. Wang Hua, Meng, Qiang and Zhang Xiaoning, (2014), Game-theoretical models for competition analysis in a new emerging liner container shipping market. *Transportation Research Part B*

Abstract:

This paper develops three game-theoretical models to analyze shipping competition between two carriers in a new emerging liner container shipping market. The behavior of each carrier is characterized by an optimization model with the objective to maximize his payoff by setting optimal freight rate and shipping deployment (a combination of service frequency and ship capacity setting). The market share for each carrier is determined by the Logit-based discrete choice model. Three competitive game strategic interactions are further investigated, namely, Nash game, Stackelberg game and deterrence by taking account of the economies of scale of the ship capacity settings. Three corresponding competition models with discrete pure strategy are formulated as the variables in shipment deployment are indivisible and the pricing adjustment is step-wise in practice. A -approximate equilibrium and related numerical solution algorithm are proposed to analyze the effect of Nash equilibrium. Finally, the developed models are numerically evaluated by a case study. The case study shows that, with increasing container demand in the market, expanding ship capacity setting is preferable due to its low marginal cost. Furthermore, Stackelberg equilibrium is a prevailing strategy in most market situations since it makes players attain more benefits from the accommodating market. Moreover, the deterrence effects largely depend on the deterrence objective. An aggressive deterrence strategy may make potential monopolist suffer large benefit loss and an easing strategy has little deterrence effect.

3. Meng, Q., Liu, Z., Wang, S., (2014), Asymmetric stochastic user equilibrium problem with elastic demand and link capacity constraints. *Transportmetrica A: Transport Science*. 01/2014; 10(4).

Abstract:

This paper focuses on model development and algorithm design for the general stochastic user equilibrium (SUE) problem with elastic demand, asymmetric link travel time functions and link capacity constraints. It first defines the generalised SUE conditions using generalised link travel time. An equivalent variational inequality (VI) model for these generalised SUE conditions is then developed and it is rigorously proven to be monotone and uniform Lipschitz-continuous. These two properties of the proposed VI model ensure the global convergence of the self-adaptive prediction –correction algorithm incorporating cost averaging method as a solution algorithm. Finally, a numerical example is utilised to assess the performance of the proposed VI model and solution algorithm.

Published Technical Papers (with Abstracts)

4. Liu, Z., Wang, S., Meng, Q., (2014), Optimal Joint Distance and Time Toll for Cordon-based Congestion Pricing. *Transportation Research Part B*, 69, 81-97.

Abstract:

This paper addresses the optimal toll design problem for the cordon-based congestion pricing scheme, where both a time -toll and a nonlinear distance-toll (i.e., joint distance and time toll) are levied for each network user's trip in a pricing cordon. The users' route choice behaviour is assumed to follow the Logit-based stochastic user equilibrium (SUE). We first propose a link-based convex programming model for the Logit-based SUE problem with a joint distance and time toll pattern. A mathematical program with equilibrium constraints (MPEC) is developed to formulate the optimal joint distance and time toll design problem. The developed MPEC model is equivalently transformed into a semi-infinite programming (SIP) model. A global optimization method named Incremental Constraint Method (ICM) is designed for solving the SIP model. Finally, two numerical examples are used to assess the proposed methodology.

5. Liu, Z., Meng, Q., Wang S., (2014), Variational inequality model for cordon-based congestion pricing under side constrained stochastic user equilibrium conditions. *Transportmetrica,* 10(8), 693-704

Abstract:

A major objective of the practical implemented cordon-based congestion pricing schemes is to maintain the traffic conditions within the cordon area, which is rarely considered in most of the existing studies. Thus, this paper addresses the optimal toll charge pattern that can restrict the total inbound flow of each cordon to a predetermined threshold. The toll charges on all the entry links of one cordon are required to be identical, for the ease of implementation and users' recognition. The users' route choice behaviour is assumed to follow stochastic user equilibrium (SUE) with asymmetric link travel time functions. It is shown that such an optimal toll charge pattern can be attained by solving a SUE problem with side constraints. A variational inequality (VI) model is first proposed for the optimal toll pattern, where the monotone property of this model is rigorously proved. Then, a convergent self-adaptive prediction and correction method can be adopted for solving the VI model. It is shown that when used in practice, the solution method only needs traffic counts on entry links of each cordon.

6. M.W. Brantley, L.H. Lee, C.H. Chen and A. Chen, (2014), An Efficient Simulation Budget Allocation Method Incorporating Regression for Partitioned Domains . *Automatica,* Volume 50, Pages 1391–1400

Abstract:

Simulation can be a very powerful tool to help decision making in many applications but exploring multiple courses of actions can be time consuming. Numerous ranking and selection (R&S) procedures have been developed to enhance the simulation efficiency of finding the best design. To further improve efficiency, one approach is to incorporate information from across the domain into a regression equation. However, the use of a regression metamodel also inherits some typical assumptions from most regression approaches, such as the assumption of an underlying quadratic function and the simulation noise is homogeneous across the domain of interest. To extend the limitation while retaining the efficiency benefit, we propose to partition the domain of interest such that in each partition the mean of the underlying function is approximately quadratic. Our new method provides approximately optimal rules for between and within partitions that determine the number of samples allocated to each design location. The goal is to maximize the probability of correctly selecting the best design. Numerical experiments demonstrate that our new approach can dramatically enhance efficiency over existing efficient R&S methods.

Conference Papers (with Abstracts)

1. Sou, W. S. and Ong, G. P. (2014), A Statistical Study on International Commodity Value-Weight Trends. ***The 5th International Conference on Transportation and Logistics (T-LOG), 28-30 July 2014, Bangkok, Thailand.***

Abstract:

International freight transportation has grown rapidly in the last decades. Dramatic economic, technical and market changes including widespread internet adoption, rapid advances in information and communication technologies and the globalization of supply chains have been observed around the world. These changes are likely affecting the demand for freight transportation as well as the type and prominence products shipped by commodity group. This paper focuses on the study of value-weight trends for commodities between different trading countries as well as comparing the value-tonnage trends for commodities carried by different transport modes. Statistical models were developed in the paper for key commodity groups to determine value-tonnage ratios trends in different international trade routes. It was found that value-tonnage ratios are important in identifying trends in freight generation and commodity flow. Implications of the obtained modelling results are also discussed in the paper.

2. Chu Longjia, T. F. Fwa and H. Nishijima, (2014), Container Port Operational Performance Assessment. ***The 5th International Conference on Transportation and Logistics (T-LOG), 28-30 July 2014, Bangkok, Thailand.***

Abstract:

With today's rather comprehensive port infrastructure and facilities information made available on public-domain Internet websites by port authorities and operators, it is possible to collect very good quality detailed data and information from such sources alone. This paper presents a case analysis based on 40 major ports in East and Southeast Asia. It demonstrates that good quality port infrastructure and container handling facilities data obtained can be used to derive a statistically significant predictive model of annual port throughputs. The derived information offers meaningful port productivity evaluation and efficiency benchmarking among the 40 ports analyzed. The analysis makes use of the commonly available technique of statistical regression to establish the predicted level of performance. The simplicity of the approach, plus the fact that all required inputs are public domain data obtainable from port websites, permits owners/ operators of individual ports or any other users to perform additional analysis if required.

3. Ghim Ping ONG, Yin Lu, (2014), An Exploratory Study on Ship Dwell Time in International Ports. ***The 5th International Conference on Transportation and Logistics (T-LOG),*** **28-30 July 2014, Bangkok, Thailand.**

Abstract:

This paper develops a count data model to describe ship dwell time of over 2000 vessels which called at 61 major world container ports, by various variables including not only vessel size and the level of demand, but also the level of service of each port such as efficiency of port handling and other facilities. The model will be very useful when business entities seek to evaluate the efficiency of a container port.

Conference Papers (with Abstracts)

4. S.H. Ng, J. Yuan, (2014), Uncertainty Quantification of CO2 Reduction Potentials for Maritime Shipping. *The International Conference on Logistics and Maritime Systems*, 27-29 August 2014, Rotterdam, Netherlands

Abstract:

With increasing global concern for climate change and global warming, it is necessary to control and reduce the greenhouse gases (GHG) emissions. In 2007, 870 million tonnes of CO2 were emitted from international shipping, contributing 2.7% of the total global CO2 emissions (MEPC59 report, 2009). With sustained growth in shipping, maritime CO2 emissions are projected to increase by at least twofold by the year 2050. Therefore it is important to improve shipping efficiency in order to reduce the total GHG emissions from the shipping industry. The International Maritime Organization (IMO) has recently proposed several operational and technical measures to improve shipping efficiency and reduce GHG emissions. The abatement potentials estimated for these measures have been further used by many organizations to project future GHG emission reductions and plot Marginal Abatement Cost Curves (MACC). However, the abatement potentials estimated for many of these measures can be highly uncertain as many of these measures are new, with limited sea trial information. Furthermore, the abatements obtained are highly dependent on ocean conditions, trading routes and sailing patterns. When the estimated abatement potentials are used for projections or MACCs, these 'input' uncertainties are often not clearly displayed or accounted for, which can lead to overly optimistic or pessimistic outlooks. In this work, we first verify and analyze the operational and technical measures proposed by IMO. The cost effectiveness of the measures are studied and ranked to evaluate the possible cost saving measures, and emission abatement potentials in 2020 are estimated. Recognizing the high uncertainty in these estimates due to the input uncertainties of the abatement potentials and costs for each individual measure, we further propose a methodology to systematically quantify and account for these input uncertainties on the overall abatement potential (emission) forecasts. Such an approach provides a fuller and more accurate picture of abatement forecasts and potential reductions achievable.

5. BALANTIC, Karmen, GRADIC, Klara, ZUMER, Tom and VIZINGER, Tea, (2014), A Comparative Study of the Nearest Neighboor and Arbitrary Insertion for the Travelling Salesman Problem. *The 11th International Conference on Logistics & Sustainable Transport, ICLST 2014*, 19-21 June 2014, Celje, Slovenia

Abstract:

In this paper, the Travelling Salesman Problem (TSP) is being discussed. TSP is a problem, where the salesman visits all the cities exactly once and then returns to the starting point, while the shortest path is being travelled. For TSP solving, there are many heuristic algorithms, which return relatively good solutions but not necessarily optimal. In the paper two algorithms, Nearest Neighbor (NN) and Arbitrary Insertion (AI) are tested taking into account a security company case. We consider the Euclidian distances between the nodes and the actual street network distances. Case study shows that both algorithms returns the same sequence if we consider Euclidian distances, while using actual distances the better result corresponds to the use of AI algorithm.

Conference Papers (with Abstracts)

6. C.H. Zhou, E.P. Chew, L.H. Lee, (2014), System Evaluation and Storage Allocation Problem in Grid-Act Based Transhipment Hub. ***The International Conference on Logistics and Maritime Systems,*** **27-29 August 2014, Rotterdam, Netherlands**

Abstract:

The global container trade, especially transshipment business, has enjoyed tremendous growth in the past decades and is expected to continue in the future. However, the capability of conventional maritime industry gradually mismatches with current demand. Therefore, in order to win the battle in global competition, maritime industry, especially transshipment industry should pursue higher operation/productivity efficiency, storage/transportation capacity and land/onboard space utilization. As a solution, two major changes are brought up: 1) the traditional manually operated terminals are gradually replaced by automated container terminals (ACT) due to the increasing man-power cost and the limited land for expansion and 2) new equipment is designed and equipped to terminals. GRID system, a new conceptual yard-side handling device, is designed by BEC industries LLC to replace or reduce conventional equipment such as RMG and vehicle. Integrated with high-speed ground transportation system, this study proposes an ACT design using GRID system for transshipment hubs, named GRID-ACT.

In the first part of this study, the features of GRID system and GRID-ACT were introduced. The primary challenge of single GRID system lied on the control logic of transfer unit - an overhead transfer vehicle. In order to reduce the potential congestion in GRID, a real time control logic was proposed and implemented in the simulation model. The GRID throughput in different sizes was examined by simulation experiment. It showed that the throughput drops as the layout length expands and was almost the same when the width increases. For GRID-ACT, a simulation model was also proposed for performance evaluation. Compared with single GRID design in the same capacity, the analytical result revealed that GRID-ACT performs far better. Besides, GRID-ACT was proven to be a promising solution in terms of the land utilization and capacity from analytical comparison among GRID-ACT and other advanced contemporary ports.

In the second part, the study investigated storage allocation problem in GRID-ACT from a higher view. Instead of determining precise container allocation, this study focused on section level, i.e. the number of containers assigned to each section during a period of time. A MIP model was developed for the problem to optimizing the resource cost and operation cost. Two heuristic algorithms based on smart allocation strategy were developed for solving the problem. Numerical experiments were conducted to evaluate the performance of the proposed model and corresponding algorithms in both small and large-scale environments. Besides, both smart allocation strategy and random allocation strategy were tested in the GRID-ACT simulation model.

This is the first study in maritime that proposes GRID concept and GRID-ACT design. Two simulation models for system evaluation were proposed. The relation between design and throughput was discussed in analytical study. In addition, a MIP model for storage allocation problem in GRID-ACT and corresponding heuristic algorithms based on smart allocation concept were proposed. In conclusion, GRID and GRID-ACT were proven to be promising solutions to future global terminal challenges.

.

CMS Research Seminars

1. An Explorative Study on GRID Frame Based Automated Container Terminal, by Researcher Dr. Jiang Xinjia (Track Leader: Assoc/Prof Lee Loo Hay)

Seminar Abstract:

Under the pressure of increasing vessel size, land scarcity and tight labor constraint, port authorities are trying to deploy more effective container handling system so as to increase the throughput of the current container terminals without increasing the labor requirement. Automated Container Terminals (ACT) are potential candidates for improving the performance of container terminals. In this project, we explore a new automated container terminal concept. Under this concept, the container terminal is automated with an overhead grid rail structure which covers a wide area of the terminal, directly interfaced with the quay crane, gate buffers and inspection area. The container-handling devices, called Transfer Units (TU), travel on the overhead grid rails and have access to any part of the container yard, thus eliminating the need of ground vehicles. The grid system based ACT stands out in maximizing land utilization, two to three times the storage density of typical port layout, which is a vital advantage in consideration of the scarcity of yard land like Hong Kong and Singapore. More detailed features will be demonstrated in the presentation.

2. A study on refueling strategies with Bunkering Contracts , by Researcher Dr. Pedrielli Giulia (Track Leader: Assoc/Prof Lee Loo Hay)

Seminar Abstract:

Bunker fuel constitutes 40% of the total costs for a liner shipping company, hence methods supporting the efficient bunker management and suggesting effective bunkering strategies represent a key factor for liner shipping companies. Developing these methods, several criticalities need to be considered, such as the high bunker fuel prices and their variability among different ports as well as in time. Bunker contracts are widely adopted to hedge against such variability guaranteeing both the bunker buyer (i.e., the liner company) and the fuel provider a certain fuel amount under agreed price conditions. Nonetheless, a contract, intuitively, has remarkable impact on the bunkering strategies (where to purchase fuel as well as how much fuel to buy) and, as a consequence, the navigation policy, i.e., the speed to keep on each leg of the service. However, the bunkering with contract problem has received little attention in the maritime literature.

In this contribution we refer to a realistic bunkering contract form and, assuming known the parameters of the contract, we solve the problem of selecting the bunkering ports and the bunker to buy on contract or at spot at each port of call together with the optimal sailing speed. The resulting model is a valuable tool to evaluate the impact of the contracting decision over the operational behavior of a vessel as well as to evaluate the convenience of the set contract parameters with respect to different price scenarios.

3. Reoptimizing Shipping Routes and Recovery Plans under Operational Uncertainties: Problem Statement and Initial Software Demo, by Researcher Dr. Du Yuquan (Track Leader: Assoc/Prof Meng Qiang)

Seminar Abstract:

During the sailing operations of containerships, various kinds of uncertainties, such as bad weather and port closure or congestion, are always breaking the prescribed sailing schedules of ships. This might cause bunker consumption increase for catching schedules, cargo delays and delay propagation along the voyage, and cargo misconnection at transshipment ports. We identify four optimization problems on ship sailing plan recovery under operational uncertainties: (a) sailing plan recovery in a long haul by shipping & port coordination; (b) weather re-routing in a long haul with port window determination; (c) voyage-based sailing plan recovery by shipping & port coordination; and (d) network-based sailing plan recovery. The four optimization problems might interest shipping lines in different view angles, and together provide alternative methods of sailing plan recovery for shipping lines.

CMS Research Seminars

4. Calculation principle of marine propulsion system, by Researcher Dr. Zhao Feiyang (Track Leader: Assistant Prof Yang Wenming)

Seminar Abstract:

The basic goal of this study was to get the ship hull, marine engine and propeller matched to achieve the desired ship sailing speed. Then the fuel consumed and exhaust pollution from container ships could be predicted, under different engine loads and ship sailing velocities by the marine propulsion model. The simulation results in terms of fuel consumption rate, engine output power and vessel speed were validated by measured data from Engine manufactory and Vessel Corporation. And the errors between predicted and measured data were considered acceptable due to the simplification of huge marine engine system. Meanwhile, the resistance force during real navigation could not be precisely reflected, and then it influenced the predicted results of sailing speed. At last, the packed marine propulsion model was implanted into the whole ship voyage model. The information of sailing vessel such as velocity, heading angle, fuel consumed and exhaust emissions could be monitored in time-varying along a desired route.

5. Bunker procurement planning for container liner shipping companies: a multi-stage stochastic programming approach, by Researcher Mr. Wang Yadong (Track Leader: Assoc/Prof Meng Qiang)

Seminar Abstract:

Bunker procurement risk arising from the bunker price fluctuation has significantly affected stable operation of container liner shipping companies. In order to hedge the bunker procurement risk, this paper introduces a novel multi-stage bunker procurement decision process (MBPDP), in which the shipping company purchases bunker from both futures contracts and risky spot market instead of solely relying on the spot market to meet demand in each stage. The risk hedging effect lies in that the company can initialize futures contracts in the first stage and rebalance them in subsequent stages based on the up-to-date bunker price information in the spot market. This feature thus enables the procurement to reflect the new trend of price movement. This procurement process is then formulated as a mean-variance minimization model in terms of the procurement costs and is solved by a scenario tree based multi-stage stochastic programming approach. Numerical examples show that the procurement risk can be effectively hedged when the futures contracts can be purchased and rebalanced compared with that when all bunker is bought from spot market..

6. A new perspective, an old problem: Revenue Based Empty Container Repositioning (R–ECR), by Researcher Dr. Pedrielli Giulia (Track Leader: Assoc/Prof Lee Loo Hay)

Seminar Abstract:

Empty container repositioning is about finding the best strategy in terms of the amount of empty containers to transfer between ports of call considering all the service routes of a liner company. Specifically, a repositioning strategy is considered the best if it minimizes the operational repositioning costs fulfilling the demand at each location in the service network. Due to the complexity of the networks, the volatility in the demand, and the long lead time of the service routes, to find the best repositioning strategy still remains a challenge for liner companies.

Nevertheless, if empty containers are repositioned aiming at only fulfilling the demand, without considering the resulting yield, it is possible that the revenue obtained at a port might not justify the cost incurred to bring the empty container back.

CMS Research Seminars

To our knowledge, no systematic approach has been proposed to support the decision makers in the activity of determining repositioning strategies which maximize the network revenues.

This work aims at partially filling this gap by developing models and efficient solution approaches to help estimating the repositioning costs and identifying repositioning strategies that are able to maximize the network revenues. The problem being tackled is still the operational repositioning problem. The costs are interpreted as the control mechanism the equipment office uses to influence the behavior at each network location.

7. Pendulum Service – A Solution for Trade Imbalance in Archipelago Countries, by Researcher Dr. Bagus Hario Setiadji (Track Leader: Prof Fwa Tien Fang)

Seminar Abstract:

Trade imbalance may be occurred on two regions with different regulations, economic growth and markets being serviced. This could not only involve markets in between two or more countries, but also markets in one country that consisting of many islands or archipelago, such as Japan, the Philippines and Indonesia. To overcome this problem, a type of maritime routes which is involving a regular itinerary between sequences of ports, or called as pendulum service, could be proposed. To do so, several ports selected in market regions, together with their supportive infrastructures, are required to be prepared. However, to achieve trade balance on those markets, some general rules of the pendulum service are necessary to be evaluated and may not strictly be applied. In this presentation, it will be described the use of a pendulum service on a network of maritime countries (with Indonesia as a case study), and the following issues and challenges that may be encountered.

8. Zero-Inflated exponential distribution of casualty rate in ship collision, By Researcher Mr. Huang Daozheng (Track Leader: Assoc/Prof Meng Qiang)

Seminar Abstract:

There are two weaknesses in current researches into human casualty of ship collision. One is that the range of injuries or fatalities is restricted to the maximum number of casualties in a particular sample, which may not cover all the possible number of casualties in the future, because ships are becoming larger and larger. IMO has employed the injured or dead percentage of all the persons onboard to represent the casualty while it only provides several discrete values to quantify human loss in different scenarios. The other is that the assumption that the distribution of the injuries or fatalities follows certain distribution, such as negative binomial or Poisson distribution is left to be statistically tested. In this study, we consider the casualty rate, including injury and fatality rate as random variables. The variables are always within the interval of 0 to 1, regardless of the particular number of persons onboard. Then the distributions of the variables are investigated using historical data. From historical data, we can find that there are excess zeros in historical data. Zero-inflated models are proved to be effective in processing data with excess zeros. Furthermore, the probability density of the variable decreases rapidly as the casualty rate becomes larger. Thus, zero-inflated exponential distribution is assumed to fit the data. The parameters of the distributions are estimated by maximum likelihood estimation (MLE). Finally, the assumption is tested by chi-square test.

CMS Research Seminars

9. Approximate Dynamic Programming with application, By Dr. Chen Weidong (Track Leader: Assoc/ Prof Bressan Stephane)

Seminar Abstract:

We start with the computational challenges arises from stochastic dynamic programmings. This seminar will talk about the general technique (Approximate value iteration), which is presented using a Monte Carlo-based method for approximating the expectation. A working example will be provided.

10. Modeling to Surface Ship Hydrodynamics for Fuel Consumption Estimation: Simulation Framework Development, by Researcher Dr. Yang Jiasheng (Track Leader: Assoc/Prof Tan Woei Wan)

Seminar Abstract:

It is well known that ship routing is defined as a procedure to determine an optimal route based on the weather forecasts, the characteristics of a specific ship, and sea states for a particular voyage, fuel consumptions and gas emissions and so on. The optimal route can be regarded as the voyage route with safety and comfort, maximum energy efficiency, minimum time consumption, or the combinations of the above factors. The reliability of the optimal route derived from the ship routing system is mainly based on the estimation accuracy of ship hydrodynamics. The focus of this talk will be on the simulation methodology development of ship dynamics. The proposed methods will be further used to predict fuel consumption and gas emission after calibration and validation.

11. Quantitative Assessment of CO2 Emission Reduction for Maritime Industry, By Researcher Dr. Yuan Jun (Track Leader: Assoc/Prof Ng Szu Hui)

Seminar Abstract:

With an increasingly concern about the climate change and global warming, it is necessary to control and reduce the greenhouse gases (GHG) emission. Shipping industry is considered to have a significant contribution to the GHG emission. Therefore it is important to improve the shipping efficiency in order to reduce the total GHG emission. International Maritime Organization (IMO) has proposed several operational and technical measures to reduce GHG emission. The abatement potentials estimated for these measures have been used by many organizations to project GHG emission reduction However, the abatement potentials estimated for many of these measures can be highly uncertain as many of these measures are new with limited sea trial information and the abatements obtained are highly dependent on ocean conditions, trading routes and captain's sailing patterns. When the estimated abatement potentials are used for projections, these 'input' uncertainties are often not clearly displayed or accounted for, which can lead to overly optimistic or pessimistic outlooks. In this work, we propose a methodology to systematically quantify and account for these input uncertainties in the overall abatement potential 'output' forecasts. This provides a fuller and more accurate picture of abatement forecasts and potential reductions achievable.

CMS Research Seminars

12. The transportation network design problems: recent advances, by Researcher Dr. Wang Hua (Track Leader: Assoc/Prof Meng Qiang)

Seminar Abstract:

In recent 15 years, we have witnessed a fast growth in the studies on the transportation network design problem (NDP). Several emerging and important factors have been integrated into the problem, such as time-variant traffic dynamics and uncertain traffic parameters. To address these emerging challenges, transportation researchers have developed a number of new NDP models and related solution algorithms. This paper aims to provide a state-of-the-art review of the NDP in the recent period. We have reviewed 86 publications in order to identify and assess the new methodological advances on recent NDPs. The involved publications are classified into four categories: stochastic NDP, time-dependent NDP, multi-objective NDP and conventional deterministic NDP. We provide methodological frameworks for the four NDP models and summarize novel characteristics of model formulations and related solution methods.

13. Big Data Based Estimation for Ship Safety Distance Distribution in Port Waters, by Researcher Dr. Zhang Liye (Track Leader: Assoc/Prof Meng Qiang)

Seminar Abstract:

The water area for a large port such as Singapore port has high ship traffic density because of the continuously increasing international seaborne and behaviors of ships sailing in in the port waters exhibit high diversity. It is utmost important for ships to maintain a minimum safety distance when they move in and out the port waters in order to avoid the accident caused by ship collisions. This study aims to estimate the probability distributions for the ship safety distance by using the big AIS data. It further investigates the thirty six navigation scenarios classified by ship type and size, visibility (i.e., daytime and night), and ships' moving direction (i.e., crossing, head-on and overtaking). The ship safety distances with different ship types and sizes are first examined by the non-parametric statistical tests. A tangible approach incorporating the maximum likelihood estimation (MLE) and Kolmogorov-Smirnov (K-S) test techniques is designed to determine the best fitted probability distribution with the parameters calibrated by the big AIS data for the ship safety distance. It is found that the lognormal and gamma distributions can well fit the ship safety distance in the Singapore port waters according to the big AIS data from Singapore port.

14. Strategic Pricing in Port Networks: Empirical Research and Evidence, by Researcher Mr. Yong Kuan Chen

Seminar Abstract:

The paper demonstrates how interaction between ports in a network can be analysed in two steps. The first step is econometric analysis to estimate port's tariff response functions and examine how ports set their tariff decision. The second step is graphical analysis that involves the identifying of the network relationship based on the results obtained from the first step.

The procedure is applied to analyse the network relationship between ports in the three regions in Australia, namely Queensland, South Australia and Victoria, and Western Australia. The result provides an insight into strategic interaction in the port network not previously seen in the literature. Especially it has been found that while some ports appear to strategically interact with each other in tariff setting, other ports prefer to set their own tariffs independently of each other. Moreover, strategic planning can be asymmetric rather than symmetric.

CMS Research Seminars

15. A tutorial on top commercial mathematical programming solvers and its applications to bi-level programming optimization problems in transportation, by Researcher Dr. Du Yuquan (Track Leader: Assoc/Prof Meng Qiang)

Seminar Abstract:

In studies on transportation, various optimization problems, especially mathematical programming based problems, are frequently encountered, such as linear programming, mixed-integer linear programming, and quadratic programming models. This tutorial provides a quick start for top commercial mathematical programming solvers including IBM ILOG CPLEX and Gurobi. We will address how to formulate our optimization problem in YALMIP, a MATLAB based toolbox, and to call CPLEX or Gurobi hooked behind. Moreover, we will discuss how to formulate and solve bi-level programming models which are often treated in transport network analysis and game theory. Additionally, we will also mention some implementation issues on non-convexity and KKT conditions.

CONTACT DETAILS

Centre for Maritime Studies
National University of Singapore
12 Prince George's Park
Singapore 118411

Tel: + (65) 6516 8669
Fax: + (65) 6775 6762
Email: cmssec@nus.edu.sg