NUS National University of Singapore
Centre for Maritime Studies

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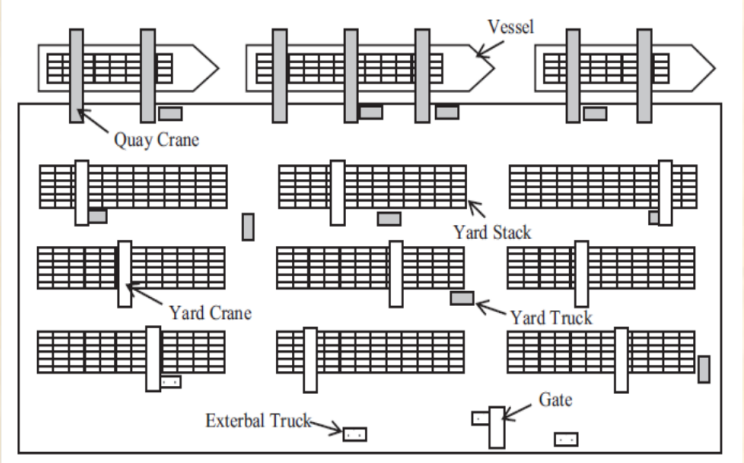
CMS RESEARCH UPDATES

MARCH 2012

RESEARCH HIGHLIGHT 1: MICROPORT BY RESEARCHER DR SUN ZHUO (TRACK LEADERS: A/PROF CHEW EK PENG & A/PROF LEE LOO HAY)

CHALLENGES

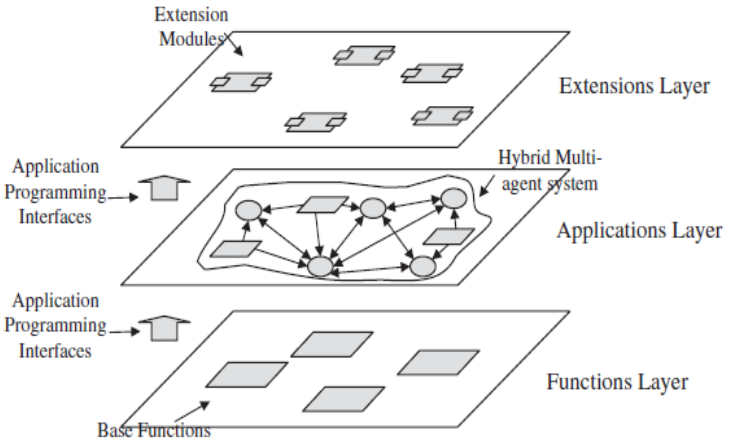
Container terminals have limited resources (land, equipment, manpower, etc.) and operational capabilities. Terminal operators also face challenges of making long-term (new port construction), short-term (resource deployment) and real-time (scheduling) decisions.

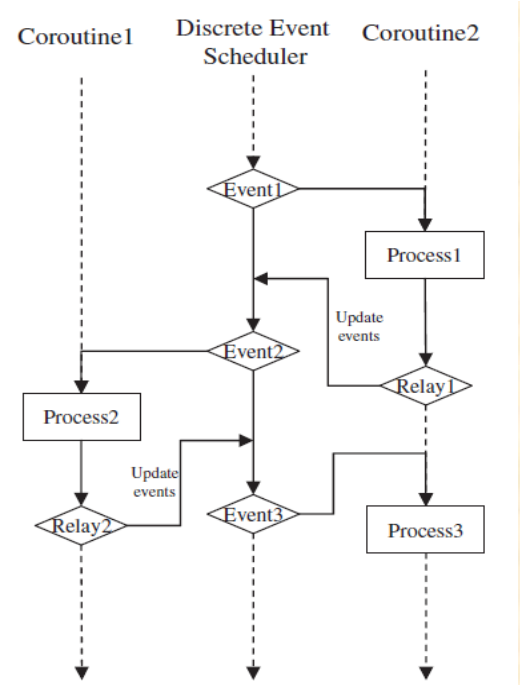


MicroPort offers a general simulation platform with which to provide an integrated and flexible modeling system for evaluating the operational capability and efficiency of different designs of seaport container terminals.

METHODOLOGY

1. Using simulation to capture uncertainties in port operations
2. Proposing a general framework with three software layers to integrate different modules
3. Using a generalized simulation structure described in the framework to facilitate model constructions





The software structure of MicroPort comprises three programming layers where lower layers support higher layers with Application Programming Interfaces (APIs). Basic functions are built in the Functions layer. Major operation processes are modeled as an improved multi-agent system in the Applications Layer. Finally the Extensions layer contains external programs which can adjust the system to produce suitable simulation models through APIs.

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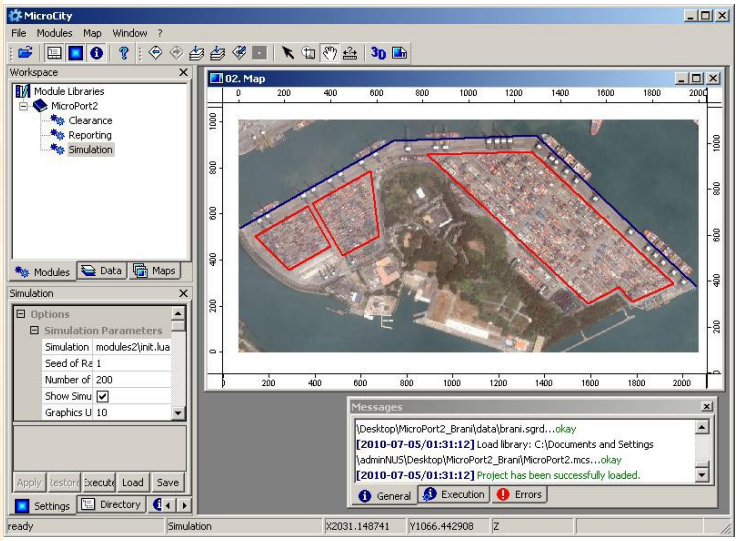
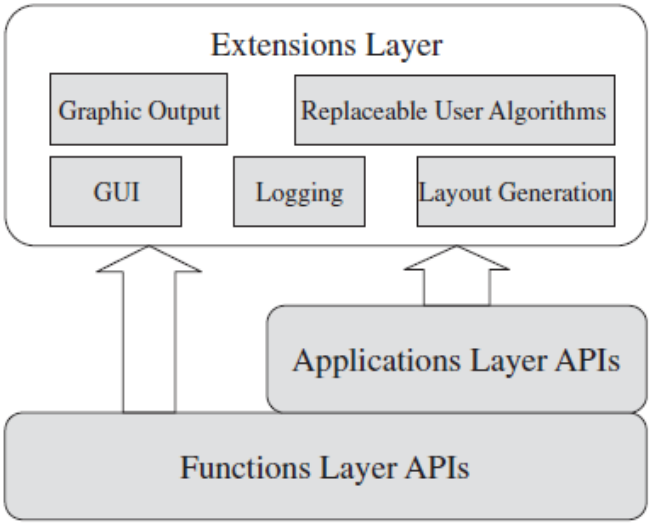




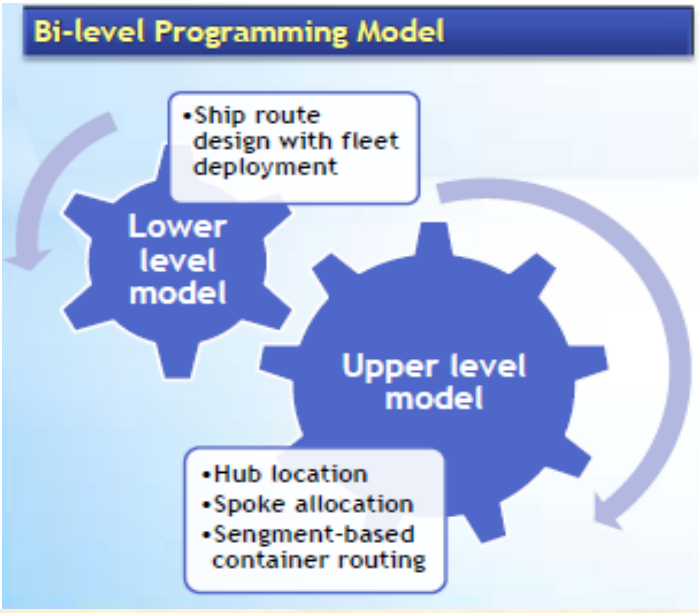
SOFTWARE

The three software layers in MicroPort provide flexibilities in developing various types of simulation models. In the Applications layer, an improved multi-agent system represents various operation processes and different equipment in container terminals. The system provides default decision processes covering major short-term, long-term and real-time planning problems in typical container terminals. Real container terminals can be simulated on this platform by using specified modules for actual configurations. Various analyses can be performed by using the platform to provide useful and insightful results for port operators and port planners and designers. This platform will greatly reduce modeling efforts and contribute to the planning and design of integrated solutions for container terminals.

RESEARCH HIGHLIGHT 2: LINER HUB-&-SPOKE SHIPPING NETWORK DESIGN BY RESEARCHER DR ZHENG JIANFENG (TRACK LEADER: A/PROF MENG QIANG)

CHALLENGES

The liner hub-and-spoke shipping network design aims to determine an optimal shipping service network including hub ports, feeder ports, ship routes and ship-fleet deployment with minimal operating cost subject to some shipping service constraints such as empty container repositioning.



SIGNIFICANCE & APPLICATIONS

- The liner shipping-network design with empty container repositioning is of great importance from both an academic perspective and practical application point of view.
- Graphical user interface for global shipping networks can provide visualized strategies for liner shipping companies.

RESEARCH HIGHLIGHT 2: LINER HUB-&-SPOKE SHIPPING NETWORK DESIGN BY RESEARCHER DR ZHENG JIANFENG (TRACK LEADER: A/PROF MENG QIANG)

METHODOLOGY

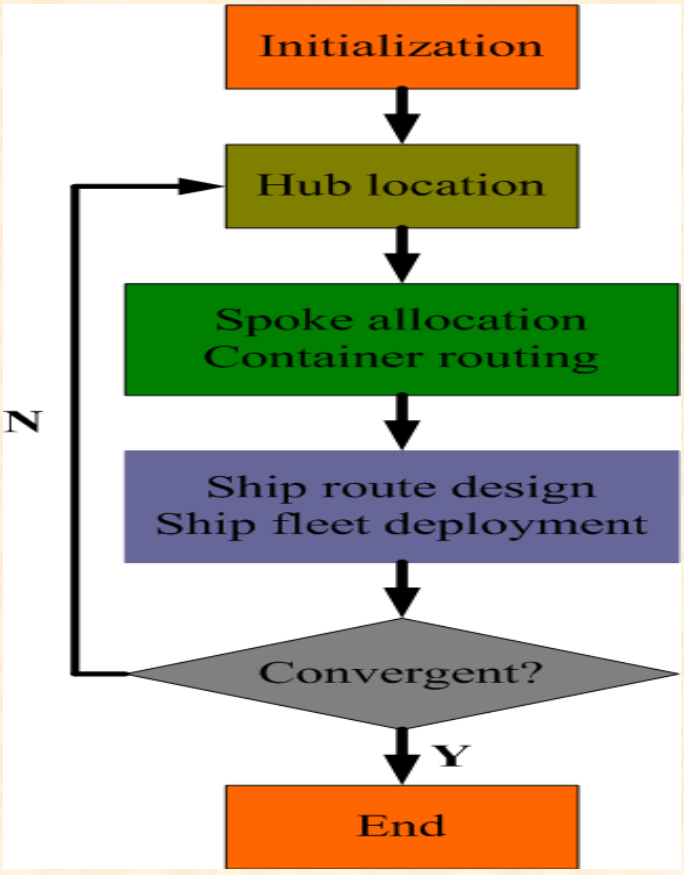
Upper level model

- Hub location
- Spoke allocation
- Segment-based container routing

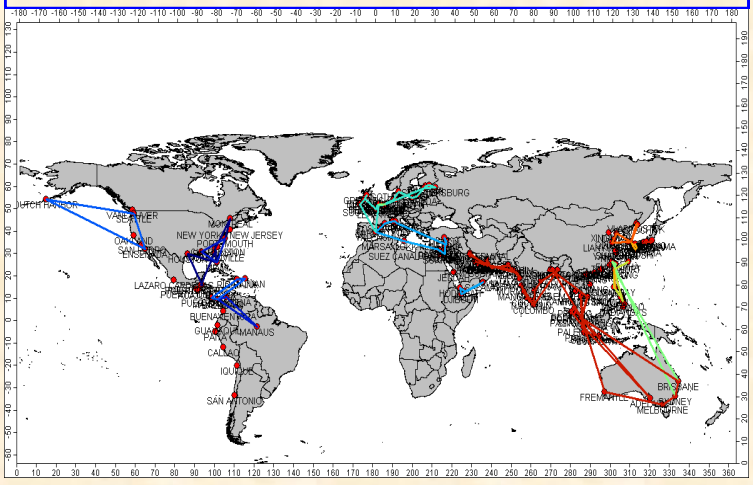
Lower level model

- Ship route design with fleet deployment

HYBRID GENETIC ALGORITHM



Graphical User Interface displaying the designed ship routes for a global shipping network



Statistical analysis for a designed global liner hub-and-spoke shipping network

Region-to-region	Number of ship routes	Number of ships		
		1500 TEUs	3000 TEUs	5000 TEUs
Europe-US	2	0	0	19
Asia-Europe	7	8	0	65
Asia-US West Coast	9	0	10	84
Asia-US East Coast	8	7	0	71
Intra-Asia	4	6	0	24
Feeder ship routes	37	18	18	52
Total	30+37=67	21+18=39	10+18=28	263+52=315

DESIGN MODELS

- The liner hub-and-spoke shipping network design can be formulated as a bi-level programming model.
- Empty-container repositioning problem is formulated as a minimum-cost flow model
- The proposed solution algorithm can efficiently solve the large scale liner shipping network design problems.

PUBLISHED TECHNICAL PAPERS (WITH ABSTRACTS ATTACHED)

1. Qiang Meng and Wang Shuaian, (2011), Liner shipping service network design with empty container repositioning, in Transportation Research Part E: Logistics and Transportation Review, 695-708

Abstract:

This paper proposes a liner shipping service network design problem with combined hub-and-spoke and multi-port-calling operations and empty container repositioning. It first introduces a novel concept - segment - defined as a pair of ordered ports served by one shipping line and subsequently develops a mixed-integer linear programming model for the proposed problem. Extensive numerical experiments based on realistic Asia-Europe-Oceania shipping operations show that the proposed model can be efficiently solved by CPLEX for real-case problems. They also demonstrate the potential for large cost-savings over pure hub-and-spoke or pure multi-port-calling network, or network without considering empty-container repositioning.

2. Qiang Meng and Xiaobo Qu, (2012), The economic importance of the Straits of Malacca and Singapore: An extreme-scenario analysis, in Transportation Research Part C: Emerging Technologies, 48:1, 258-265.

Abstract:

This paper proposes a decision tree model to estimate the loss to global economy on the hypothesis of an extreme scenario of blockade of the Straits of Malacca and Singapore. The insurance surcharges, inventory costs and the time values of cargoes, and Time Charter Equivalent rate are used to estimate the psychological loss, the loss to industries, and the loss to carriers, respectively. Interestingly, there is a pseudo-paradoxical phenomenon with respect to the loss to carriers. An illustrative example is also provided to explain the "Malacca Paradox".

3. Shuaian Wang, Qiang Meng, (2012), Liner ship fleet deployment with container transshipment operations, in Transportation Research Part E: Logistics and Transportation Review. 48:2, 470-484.

Abstract:

This paper proposes a liner ship fleet deployment (LSFD) problem with container transshipment operations. The proposed problem is formulated as a mixed-integer linear programming model which allows container transshipment operations at any port, any number of times, without explicitly defining the container transshipment variables. Experiments on the Asia–Europe–Oceania shipping network of a global liner shipping company show that more than one third (17–22 ports) of the total of 46 ports have transshipment throughputs. Computational studies based on randomly generated large-scale shipping networks demonstrate that the proposed model can be solved efficiently by CPLEX.

PUBLISHED TECHNICAL PAPERS (WITH ABSTRACTS ATTACHED)

4. Dong Yang, Miaojia L, , Xiaoning Shi, (2011), Verifying liner Shipping Alliance's stability by applying core theory, Research in Transportation Economics, Volume 32, Issue 1, 2011, 15-24.

Abstract:

The core is a vital concept in cooperative game theory and has been widely used in analyzing alliance's stability. It is especially interesting to apply core theory in liner shipping market due to the latter's exceptional characteristic of non-homogeneous cost curves as well as divisible and fluctuant demand. Having observed some new phenomena and trends in the industry, this paper studies the economic performance and stability of liner shipping alliance by applying core theory where business cooperation is partly realized by delivering joint-service with mega container ships. To demonstrate the core situation in liner shipping alliance, a cost function is first identified on the basis of two assumptions regarding cooperation: 1) sharing or pooling vessels and 2) deploying mega container ships if needed. Taking cost functions as basis, two conditions of approaching core may be groomed, i.e., collective rationality and individual rationality. The first condition is discussed from the perspective of market, while the second condition is studied within the alliance. Stability of liner shipping alliance is then observed based on these two conditions. An illustrative case study is conducted in order to show some implications and explicitly clarify the theory.

5. Shuaian Wang, Qiang Meng, Sailing speed optimization for container ships in a liner shipping network, (2012), in Transportation Research Part E: Logistics and Transportation Review, 48:3, 701-714

Abstract:

This paper first calibrates the bunker consumption – sailing speed relation for container ships using historical operating data from a global liner shipping company. It proceeds to investigate the optimal sailing speed of container ships on each leg of each ship route in a liner shipping network while considering transshipment and container routing. This problem is formulated as a mixed-integer nonlinear programming model. In view of the convexity, non-negativity, and uni-variate properties of the bunker consumption function, an efficient outer-approximation method is proposed to obtain an e-optimal solution with a predetermined optimality tolerance level e. The proposed model and algorithm is applied to a real case study for a global liner shipping company.

PUBLISHED TECHNICAL PAPERS (WITH ABSTRACTS ATTACHED)

7. Sun, Z. Lee, L.H. and Chew, E.P., (2011), MicroPort: A general simulation framework for seaport container terminals, Advanced Engineering Informatics, Issue 26, September, 80-89.

Abstract

Seaport container terminals are essential nodes in sea cargo transportation networks. As such, the operational efficiency of container terminals in handling containers passing through them plays a critical role in a globalized world economy. Many models and algorithms have been developed to address various decision problems in container terminals to help improve operational efficiency. These decision support tools are usually used separately for specific purposes. However, the problems they are trying to tackle are often interrelated. Therefore, in this regard, an evaluation tool which can capture as many operational conditions as possible for different decision problems is necessary. This paper introduces a general simulation platform, named MicroPort, which aims to provide an integrated and flexible modeling system for evaluating the operational capability and efficiency of different designs of seaport container terminals. The software structure of MicroPort comprises three programming layers: (1) the Functions layer; (2) the Applications layer; and (3) the Extensions layer. Different layers are bound by Application Programming Interfaces (APIs). Basic functions built in the Functions layer support the Applications layer in which major operation processes can be modeled by an agent-based method. External modules and decision support tools in the Extensions layer then use APIs to adjust the system to produce suitable simulation models for specific purposes.

8. Jiang, J L, E P Chew, L H Lee and Z SUN, (2011), "DEA based on strongly efficient and inefficient frontiers and its application on port efficiency measurement". OR SPECTRUM, June, p1-27.

Abstract

Data envelopment analysis (DEA) is a non-parametric analytical methodology widely used in efficiency measurement of decision making units (DMUs). Conventionally, after identifying the efficient frontier, each DMU is compared to this frontier and classified as efficient or inefficient. This paper first introduces the strongly efficient frontier (SEF) and strongly inefficient frontier (SIF), and then proposes several models to calculate various distances between DMUs and both frontiers. Specifically, the distances considered in this paper include: (1) both the distance to SEF and the distance to SIF, where the former reveals a unit's potential opportunity to become a best performer while the latter reveals its potential risk to become a worst performer, and both the closest distance and the farthest distance to frontiers, which may provide different valuable benchmarking information for units. Subsequently, based on these distances, eight efficiency indices are suggested to rank DMUs. Due to different distances adopted in these indices, the efficiency of units can be evaluated from diverse perspectives with different indices employed. In addition, all units can be fully ranked by these indices. The efficiency of 24 major Asian container ports is analyzed with our study, where the potential opportunities and potential crises of these ports are revealed and some new insights about their efficiency are provided.

CMS RESEARCH SEMINARS

1. Analysis on Container Port Capacity: A Markovian Modeling Approach, by Researcher Dr Lee Byung Kwon (Track Leader: A/Prof Lee Loo Hay)

Seminar Abstract:

Container ports handle outbound, inbound, and transshipment containers plying between the area for vessels on the quay and the storage space in the yard. Port operators typically concentrate their efforts on the container handling process with the aims of increasing the productivity of quayside operations and reducing the time in port of vessels. Recognizing that operation processes necessitate containers to stay in the storage space for a certain period before moving to other areas, the operational efficiency at the yard (in addition to that at the quayside) plays an influential role in ensuring performance measures of a container port. This study develops analytical models based on the Markov chain to estimate the port capacity under various combinations of resources, namely, quay cranes, yard cranes, and prime movers. Important performance measures representing the capacity in the proposed models are analyzed and sensitivity analyses of the port capacity are conducted through numerical experiments. The results under the suggested operational strategies are also compared.

2. Non-lane-based Car Following Model using Visual Angle Information, by Visiting Research Fellow Dr Jin Sheng (Track Leader: A/Prof Meng Qiang)

Seminar Abstract:

Car following theory is of significance in microscopic traffic flow theory. The key assumption of current car following theory is that vehicles travel in the middle of a single lane. But it is very unrealistic and is incapable of describing driving behavior in a complex traffic environment. Taking into account the lateral separation characteristics between the follower and the leader, the equation of Time-to-Collision (TTC) was modified using visual angle and introduced into the general GM model. Based on the stimulus-response framework, a non-lane-based car following model using TTC was developed. The property of the model was investigated by simulations in several driving scenarios, and it is found that the proposed model has ability to describe local and asymptotic stabilities, the lateral movement and the effect of neighboring vehicles. The results implied that this staggered car following model incorporating lateral separation greatly enhances the realism of car following behavior.

3. Rich Models for Tramp Ship Routing and Scheduling, by Visiting Prof Kjetil Fagerholt

Seminar Abstract:

Scheduling shipments of bulk cargoes can be a complicated task, especially when multiple cargoes may be on board a vessel simultaneously. Most research on such bulk ship routing and scheduling problems has focused on solving a simplified version of the real problem, which is denoted as the basic problem. However, practical problems often pose additional complexities and opportunities that are not considered in the basic problem. This study will give a mathematical model for the basic bulk ship routing and scheduling problem and for three practical extensions to it: (1) flexible cargo quantities, (2) split cargoes, and (3) sailing speed optimization. Consolidating results from various sources this study will show that, although the problems become harder to solve, significantly better solutions can be obtained by utilizing the additional flexibility provided by these extensions. Each of these extensions may increase profit contribution by 5-20%, depending on the problem characteristics. These methods have been incorporated into a commercial software product used by several shipping companies.

CMS RESEARCH SEMINARS

4. A Decomposition Method to Analyze the Performance of the Frame-bridge Based Automated Container Terminal, by Researcher Dr Hu Hongtao (Track Leader: A/Prof Chew Ek Peng)

Seminar Abstract:

In this study, we analyze the performance of a frame-bridge based automated container terminal which utilizes multi-storey frame bridges and rail-mounted trolleys to transport containers between the quay and the yard. In the previous study, we use the Markov chain to study the performance of the transfer platform with constant frame trolleys and ground trolleys. We also consider different transfer platform deployment strategies, such as the transfer platform can travel between two blocks. In recent studies, we consider the performance of the transfer platform with different loading and unloading process. And we also developed a decomposition method to consider the performance of the whole system with limited quay cranes and yard cranes.

5. Impact of Port Reform, Political and Economic Events on Maritime Traffic evolution in Chinese Ports, by Researcher Dr Yang Dong (Track Leader: A/Prof Anthony Chin)

Seminar Abstract:

Chinese ports have undergone a series of dynamic international and domestic events, economic and political reform since the foundation of the People's Republic. This study attempts to ascertain how these political, economic events and port reforms have had an impact on maritime traffic of Chinese ports by using econometric methods. Findings suggest that foreign trade drives the increase in throughput of Chinese ports, especially foreign throughput and coastal port throughput. In contrast, this increase in port throughput has led to an increase in domestic retail sales (or domestic demand) as well as more port investments. In its development, Chinese ports traffic was subject to multiple shocks. Among all the events, the Great Leap Forward has exerted the biggest influence to the throughput of Chinese ports in short term. China's accession to WTO brought an exclusive and minor effect to ports throughput, it long time effect. Rises in ports throughput were also a consequence of implementation of port policy but not as prominent as effect from economic and political events. Port structural reform is proved to be more efficient and long lasting than simple investment in the port infrastructure construction.

6. A Novel Method for Solving Large-Scale Complex Global Intermodal Liner Shipping Service Network Design Problem, by Dr Du Gang (Track Leader: A/Prof Meng Qiang)

Seminar Abstract:

"NP-hard" characteristics and several existing practical constraints constitute challenges to solving large-scale complex global intermodal liner-shipping service network design problems, in particular, the maritime and inland transportation leg. This study constructs an integrated model and proposes a novel decomposition method to solve the problem. Export and import ports from associated equipment supply points (EQSPs) in the inland leg are determined by a proposed approach, which considers trade-offs in distance, time and cost of each OD pair. A Logit-based route choice principle is also employed in determining choice of different inland transport modes (truck, train, barge or their combinations) in order to save cost for shippers. In addition, empty container flows are described on the basis of path flow and leg flow in the inland and maritime networks, respectively. Numerical experiments, based on a realistic oceanic liner-shipping network, are then carried out to validate the effectiveness and applicability of the proposed model and algorithm.

CMS RESEARCH UPDATES

CMS RESEARCH SEMINARS

7. Decision Tree–Based Model for Estimation of Work Zone Capacity, Dr Weng Jinxian (Track Leader: A/Prof Meng Qiang)

Seminar Abstract:

The ability to estimate work zone capacity accurately is imperative because accurate estimates are a key input to estimates of queue length and traffic delay in work zones. This paper aims to develop a decision tree–based model that considers 16 influencing factors to estimate freeway work zone capacity accurately. The F-test splitting criterion and the post-pruning approach are employed to grow and prune the decision tree. Freeway work zone capacity data collected from 14 states and cities are used to train, check, and evaluate the decision tree–based capacity estimation model. Statistical comparison results demonstrate that the decision tree–based model outperforms existing short-term and long-term freeway work zone capacity estimation models, especially when the input values of influencing factors are only partially available for the existing models. A comparison with the Highway Capacity Manual (HCM) also indicates that the decision tree–based model can provide a more accurate estimate of freeway work zone capacity. From the decision tree–based model, traffic engineers can easily estimate work zone capacity for a given freeway work zone by tracing a path down the tree to a terminal node. Because of its accuracy and ease of use, the proposed decision tree–based capacity model is a good alternative for traffic engineers to use in estimating freeway work zone capacity. It is expected that the decision tree–based capacity model could be applied to the HCM chapter on freeway facilities.

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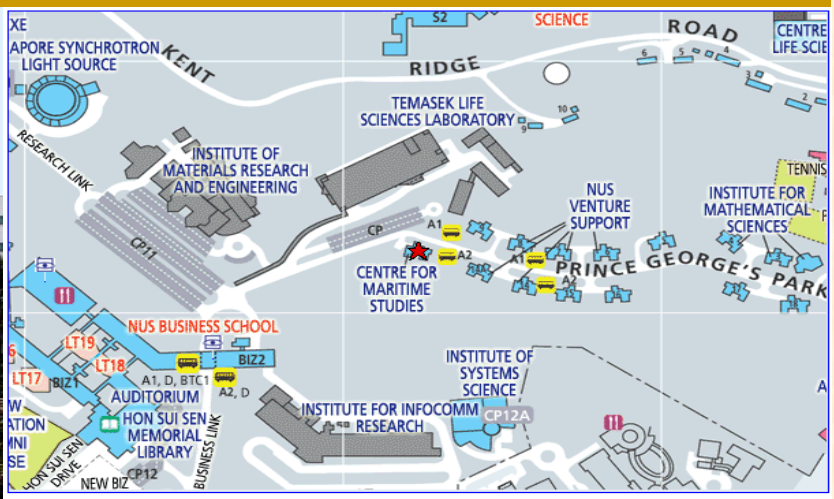

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