LOGMS

THE UNIVERSITY OF SYDNEY

UTS
UNIVERSITY OF TECHNOLOGY, SYDNEY

QUT Queensland University of Technology

Extended Abstracts Presented at the 6th International Conference on Logistics and Maritime Systems

The University of Sydney Business School CBD Campus

Level 17, 133 Castlereagh Street, Sydney, Australia

20-23 June 2016

Content

LOGMS

01 Programme

MONDAY 20 JUNE (TUTORIALS on Floor 17)

08:00 – 09:00	**Registration (Floor 17)**
09:00 – 10:30	**Tutorial 1**

Port Operations and Economics
Xiaowen Fu

10:30 – 11:00	**Morning tea (Floor 17)**
11:00 – 12:30	**Tutorial 2**

Container Line Network Design
Rommert Dekker

12:30 – 13:30	**Lunch (Floor 17)**
13:30 – 15:00	**Tutorial 3**

Cargo Routing and Empty Container Repositioning
Panagiotis Angeloudis

15:00 – 15:30	**Afternoon tea (Floor 17)**
15:30 – 17:00	**Tutorial 4**

Operation Scheduling at Container Terminals
Kap Hwan Kim

17:00 – 19:00	**Reception (drinks & canapes) on Floor 16**

TUESDAY 21 JUNE (SYMPOSIUM DAY 1)

08:00 – 09:00 **Registration (Floor 17)**

09:00 – 10:30 **Opening (Floor 17)**

Opening & Welcome
Michael Bell, Chair of the Local Organising Committee, and Elizabeth Cowley, Deputy Dean of Sydney University Business School

Keynote presentation 1: Rise of the Machines
Hugh Durrant-Whyte

Keynote presentation 2: Green Vehicle Routing
Gilbert Laporte

10:30 – 11:00 **Morning tea (Floor 17)**

11:00 – 12:30 **Industry Panel 1: Stakeholder Industrial Panel (Floor 17)** **Chair: Peter Creeden from Hamburg Süd**

12:30 – 13:30 **Lunch (Floor 17)**

13:30 – 15:30 **Session 1A (Floor 17)** **Chair: Chung-Yee Lee**

Theme: Logistics (Bullwhip effects, data and Industrial logistics)

The Bullwhip Effect of Make-to-Order Manufactures that Consider Rush Order in Two-Stage Decentralized Supply Chain Systems
Yufang Chiu, Chen-An Ma and He-Hsuan Hsu

Industrial Logistic Performance Evaluation: A Case of Bulk Feed Truck Manufacturing Company in Thailand
Kanda Boonsothonsatit and Baromasak Bedavanija

Data Driven Newsvendor Problem
Renrong Weng, Javier Loh, Giulia Pedrielli and Loo Hay Lee

Empirical Investigation of Supply Chain Structure using Network Theory
Supun Perera, Mahendrarajah Piraveenan, Michael Bell and Michiel Bliemer

13:30 – 15:30 **Session 1B (Floor 16)** **Chair: Panagiotis Angeloudis**

Theme: Ports (Port connectivity and efficiency)

Terminal Allocation with Considering Bunker Consumption
Lu Zhen

Optimal Path Design for Mesh-like Structure in GRID System
Chenhao Zhou, Zhi Chao Poh, Ek Peng Chew and Loo Hay Lee

An Integrated Approach for Operational Problems in Dry Bulk Terminals
C. Ozgur Unsal and Ceyda Oguz

Optimizing Service System Designs with Congestion by Conic Optimization Formulations
Julio C. Góez and Miguel F. Anjos

15:30 – 16:00 **Afternoon tea (Floor 17)**

16:00 – 18:00 **Session 2A (Floor 17)** **Chair: Shuaian Wang**

Theme: Ports (Berth and crane scheduling problems)

Robust Berth Allocation for Minimizing Conflicts with Planned Schedule
Fan Wang, Jinjia Huang and Zhou Xu

The Quay Crane Scheduling Problem with Steel Rope Renewals
Feifeng Zheng, Zizhen Zhang, Yanzhi Li and Songshan Guo

Measurement of Port Operational Performance using Data Envelopment Analysis
Sirawadee Arunyanart

An Integrated Scheduling of Berth and Quay Cranes with Maintenance Activities
Feifeng Zheng, Ying Li and Ming Liu

16:00 – 18:00 **Session 2B (Floor 16)** **Chair: Thalis Zis**

Theme: Maritime (Water freight)

The Potential for Water Freight in the South West UK
Sapna Chacko, Michael Roe and John Dinwoodie

The Cargo Fare Class Mix Problem Extended
Bart van Riessen, Rudy Negenborn and Rommert Dekker

The Impact of Canvasser and Bargaining Agent on Equilibrium Structure of Maritime Service Supply Chain
Fan Wang and Xiaopo Zhuo

Analytical Model to measure Sea Cargo Export Demand in Sri Lanka
Thilini Ranatunga and Baudhi Abeysekara

WEDNESDAY 22 JUNE (SYMPOSIUM DAY 2)

9:00 – 10:30 | **Industry Panel 2: Supply Chain Industrial Panel (Floor 17)** | **Chair: Thomas Vitsounis from Data 61**

10:30 – 11:00 | **Morning tea (Floor 17)**

11:00 – 12:30 | **Session 3A (Floor 17)** | **Chair: Jin Chun**

Theme: Logistics (Cross-dock scheduling, Urban consolidation and Warehousing)

Urban Consolidation Centre for Improving Shopping Mall Logistics in Singapore
Giulia Pedrielli, Laura Gunarso, Ek Peng Chew and Loo Hay Lee

Data Driven based Clustering and Routing for Third-party Logistics
Chenhao Zhou, Giulia Pedrielli, Liang Hong Lee, Loo Hay Lee and Ek Peng Chew

Sharing Storage Spaces in Warehouses Owned by Independent Profit Makers
Kap Hwan Kim, Kang Tae Park, Xiao Ruan, Xuehao Feng and Xuefeng Jin

11:00 – 12:30 | **Session 3B (Floor 16)** | **Chair: Rommert Dekker**

Theme: Maritime (Environment)

Artificial Neural Network Model for Ship Fuel Consumption Prediction with Applications to the In-Service Ship Fuel Consumption Management
Yuquan Du and Qiang Meng

The Implications of Environmental Regulation on Sailing Speed Optimization
Thalis Zis, Panagiotis Angeloudis, Michael Bell and Harilaos Psaraftis

Tactical Bunker Management for Operational Flexibility and Risk Management in SECAs
Stein W. Wallace, Xin Wang and Yewen Gu

12:30 – 13:30 | **Lunch (Floor 17)**

13:30 – 15:30 | **Session 4A (Floor 17)** | **Chair: Persa Paflioti**

Theme: Ports (Models for optimising port or terminal operations)

Collaborative Subcontracting Delivery Requests for Inter-Terminal Transshipment Containers
Dongwon Jang, Benedikt Vornhusen and Herbert Kopfer

Investigating Alternative Approach to the Gravity Model of International Trade in Evaluating International Trade Policies
Collins Teye, Michael G. H. Bell and Persa Paflioti

Massively Parallelising Genetic Algorithms on Apache Spark to Schedule Straddle Carriers
Haye Lau and Shuai Yuan

A Simulation Optimization based Platform for Container Port Capacity Planning
Haobin Li, Chenhao Zhou, Loo Hay Lee and Ek Peng Chew

13:30 – 15:30 | **Session 4B (Floor 16)** | **Chair: Qiang Meng**

Theme: Maritime (Liner shipping and freight rate)

Containership Deployment on a Liner Service
Shuaian Wang, Zhiyuan Liu, Xiaobo Qu and Lu Zhen and Hongtao Hu

Multivariate Modelling of Regional Ocean Freight Rates
Roar Adland, Steen Koekebakker and Fred Espen Benth

Will Liner Ships Make Fewer Port Calls Per Route?
Judith Mulder and Rommert Dekker

Resource Sharing Coordination for Carrier Alliances
Zhou Xu, Xiaofan Lai and Liming Liu

15:30 – 16:00 | **Afternoon tea (Floor 17)**

16:00 – 18:00 | **Session 5A (Floor 17)** | **Chair: Stein W. Wallace**

Theme: Logistics (Network designs and transport operations)

A Coalitional Game-Theoretical Approach to the Design of Express Delivery Service Network Based on Strategic Alliance
Hong Bae Kim, Byung Nam Kim and Chang Seong Ko

Network Design and Transport Operation by Assigning Cargo Aircrafts and Time-Space Network
Shunan Yu and Zhongzhen Yang and Kang Chen

Hybrid Strategies for Order Picking in a Warehouse for Fashion E-Commerce
Giulia Pedrielli, Vinsensius Albert, Ek Peng Chew and Loo Hay Lee

Construction of a Comprehensive Analysis Foundation for an Optimal Nodes Placement
Shinya Mizuno, Yoshikazu Fujisawa and Naokazu Yamaki

16:00 – 18:00	Session 5B (Floor 16)	Chair: Loo Hay Lee
	Theme: Ports (Intermodal terminal operations and intermodal transport planning)	

Scheduling and Routing of Trucks in Drayage Services with Foldable Containers
Ruiyou Zhang, Haishu Zhao and Shixin Liu

Operational Analysis Approach on Intermodal Terminal Considering Railway Traffic Linked with Container Terminal Based on Simulation
Chun Jin and Jingshu Wang

Integrated Yard Crane Deployment and Storage Allocation in a Transhipment Container Hub
Xinjia Jiang

Case Study of a Refrigerated Warehouse Design and Analysis using i-AOMA
Gyusung Cho and Kwangyeol Ryu

19:00 – 22:00 Conference Dinner (O Bar and Dining)

THURSDAY 23 JUNE (SYMPOSIUM DAY 3)

09:00 – 10:30 Session 6A (Floor 17) Chair: Kap Hwan Kim

Theme: Industrial Session 1 (Logistics Technologies)

A Study on Pick-Face Blocking Delay between two Pickers in a Wide-Aisle Circular Passage System
Boa nam, Jeonghwan Kim and Soondo Hong

How Much Energy Leaks Through a Loading Dock?
Yong-Joo Kim, Kyung-Ho Moon, Youn Keun Bhang and Jae Hyun Park

Impacts of Mega Vessel and Challenges to Ports
Hyongmo Jeon

A Study on an Order Batching Model Considering the Depot Selection
Jihyun Kim, Thuy Mo Nguyen and Soondo Hong

09:00 – 10:30 Session 6B (Floor 16) Chair: Collins Teye

Theme: Ports (Straddle Carrier Automation and Routing of AGVs in container terminals)

Straddle Carrier Automation - An Example of Research to Commercialisation
Anil Agrawal and Haye Lau

A Two-Stage Approach for Large Scale AGV Routing in the Automated Container Terminal
Zhipeng Qiu, Ek Peng Chew and Loo Hay Lee

Real-time Deadlock-free Routing for AGV System in Container Terminal
Qitong Zhao, Ek Peng Chew and Loo Hay Lee

10:30 – 11:00 Morning tea (Floor 17)

11:00 – 12:00 Session 7A (Floor 17) Chair: Kap Hwan Kim

Theme: Industrial Session 2 (Automation in Container Terminals)

Determination of AGV Lane Directions in an Automated Container Terminal for Optimal Traffic Flow
Taekwang Kim and Kwang Ryel Ryu

A Simulation Study of the Operation for an Automated Container Terminal with Overhead and Floor Rails
Jeong Hoon Seo, Xuefeng Jin, Kap Hwan Kim and Byung-Nam Kim

11:00 – 12:00 Session 7B (Floor 16) Chair: Xiaowen Fu

Theme: Maritime (Carrier Alliances, port connectivity and Maritime transport Policies)

Emission Charge and Liner Shipping Network Configuration- An Economic Investigation of the Asia-Europe Route
Wayne Lei Dai, Xiaowen Fu, Tsz Leung Yip, Hao Hu and Kun Wang

Potential Impacts of International Maritime Transportation Policies on the Pacific Region: A Case Study in Melanesia
Yu Lu, Ryuichi Shibasaki and Hironori Kato

12:00 – 12:45 Conference Closure (Floor 17)

Word from the Chairman of the LOGMS Scientific Advisory Committee
Rommert Dekker

Word from the host of LOGMS 2017
Stein W. Wallace

Word from the host of LOGMS 2016
Michael G. H. Bell

12:45 – 14:00 Lunch (Floor 17)

14:00 – 18:00 Tour of Patrick and DP World Terminals (Meet at the entrance to 133 Castlereagh Street)

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02 Foreword by the Chair of the Local Organising Committee

Foreword by Professor Michael Bell

The world of maritime logistics has never looked more challenging than now. Persistent over capacity in container shipping, driven by the post-GFC delivery of megacarriers, is depressing freight rates. So far, container carriers have managed to absorb the excess capacity through a combination of slow steaming and less port calls, facilitated by alliances between carriers. However, slowing economic growth, particularly in China, the downsizing of some consumer durables, and the shortening of some supply chains is impacting the growth in volume of containerised international trade and adding to the downward pressure on freight rates. Before the GFC, the growth in container flows were a multiple of GDP growth; now and for the foreseeable future it will be a fraction of GDP growth. Fortunately, big falls in the price of oil have helped container carriers remain solvent, but this situation is unlikely to persist. Fortunately there are signs that the market has begun to correct, with the delivery of new ships slowing to a trickle.

The increase in the size of new carriers, both through new deliveries and through the cascading of ships from the Asia-Europe trade route to other trade routes, coupled with static or falling frequencies of port calls, is leading to larger batches of containers being loaded and unloaded, putting a strain on maritime container terminals and leading to congestion and delay at ports. However, this trend is also creating opportunities. In order to handle bigger batches of containers more efficiently and reliably, some terminals are turning to automation. Automatic stacking cranes are increasingly widespread. Australia has found its own solution with the successful introduction of driverless straddle carriers (Autostrads) from Kalmar, a major sponsor of this conference. LOGMS2016 participants will be able to see Autostrads in action in the Patrick terminal at Port Botany on 23 June.

Dry bulk shipping has also been experiencing a torrid time lately, as an early indicator of declining economic growth is a reduction in demand for raw materials, like iron ore and metallurgical coal, leading to fewer fixtures for bulk carriers. This has been matched by an oversupply of capacity resulting from the delivery of bulk carriers ordered in the expectation of continued growth. An oversupply of crude oil, however, has boosted the demand for crude oil carriers to store the excess production, in part for speculation. Commodity traders have been holding crude oil to benefit from the difference between the current low spot price and a higher price for future delivery (in the jargon of financial speculation, contango plays).

Big changes in energy trades are under way, with the demand for thermal coal experiencing resistance due to concerns about air quality (particularly in China) and greenhouse gas induced climate change, but perhaps most significantly, due to the abundant availability and low cost of LNG. Thanks to global maritime distribution by LNG tankers, LNG offers unparalleled energy supply security and reliability at a global level. Floating liquefaction plants (FLNG) are opening up offshore gas resources while floating storage and regasification units (FSRU) are making gas available to more port cities round the world. Australia will soon overtake Qatar as the world's largest supplier of LNG, so retaining its importance in global energy supply chains despite waning interest in thermal coal.

Perhaps the biggest challenge facing maritime logistics today is automation. After the traumatic social revolution brought about by the container revolution and the mechanisation of container handling in the 1960s and 1970s, intermodal transport is now being transformed again by automation. Automation is also transforming pit to port movement in the mining industry with automated trains moving iron ore from mines to terminals in Western Australia and then automated conveyor, stacker-reclaimer and shiploader systems in the terminals. Just as significant is the automation of back office operations in ports, shipping lines and along supply chains. Although automation will not bring about the mass redundancy of stevedores as containerisation once did, it will again change the skill sets required in maritime logistics. Eventually automation will reach shipping itself, with the development of robot ships. Although there is as yet no IMO convention governing the deployment of robot ships, the technology is advancing rapidly to the point where such a convention will be needed soon.

LOGMS2016 is providing a timely forum in Sydney for the discussion of these and other issues that are transforming maritime logistics. With participants from China, Germany, Hong Kong, Japan, Korea, Netherlands, Norway, Singapore, Sri Lanka, Taiwan, Thailand, Turkey, UK and of course Australia, the dialogue will be truly international. The balance of academic and industry participation will provide a fertile environment for the exchange of views and experience. Australia, being an island economy and a major player in global mineral and energy supply chains, is particularly dependent on maritime logistics and, because of the scale of its bulk exports, will play a decisive role in future developments in bulk shipping. Through LOGMS2016, we hope to make a positive contribution to the development of maritime logistics.

Michael Bell,

Professor of Ports and Maritime Logistics and Chair of the Local Organising Committee,
Institute of Transport and Logistics Studies (ITLS)
University of Sydney Business School

28 May 2016

03 About LOGMS

About LOGMS

The objective of this conference is to provide a forum for participants from universities and related industries to exchange ideas on the latest technical, operational and economic developments in container and bulk logistics and their related maritime systems. Logistical developments continue to drive the growth of international trade, leading to more complex global supply networks typically involving maritime, inland waterway, road and rail transportation systems.

The first conference of this series took place in Busan, Korea in 2010 integrating various predecessor conferences like the International Conference on Intelligent Logistics Systems (IILS). The subsequent conferences in this series took place in Bremen (2012), Singapore (2013), Rotterdam (2014), and Hong Kong (2015).

04 LOGMS Scientific Advisory Committee

LOGMS Scientific Advisory Committee

05 LOGMS 2016 – Local Organising Committee

LOGMS 2016 – Local Organising Committee

Michael Bell	*University of Sydney*
Erhan Kozan	*Queensland University of Technology*
Dikai Liu	*University of Technology Sydney*
Behnam Fahimnia	*University of Sydney*
Xiaowen Fu	*University of Sydney*
Collins Teye	*University of Sydney*
Persa Paflioti	*University of the Aegean*
Supun Perera	*University of Sydney*

06 Sponsors of LOGMS 2016

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07 Keynote Sessions

Keynote Presentation 1: Rise of the Machines

By Prof. Hugh Durrant-Whyte

Digital disruption – data analytics, computing, automation and robotics – is transforming the world we live in, challenging and destroying conventional business models, but in the digital wake providing new opportunities for industries not yet dreamed of and opportunities for profound social and economic change. This conversation will paint an Australian picture of digital disruption, focusing on the rise of robotics in key industry supply chains such as cargo handling, mining and agriculture, to the increasing use of massive real-time data in these sectors, for modelling for prediction and for decision making. Together these are building a future of data-driven and autonomous operation for whole industries in Australia. The conversation will also talk about how this disruption is creating new businesses in robotics, data science and autonomous decision making – and what this will mean for the future of the economy and society in Australia and internationally.

About Prof. Hugh Durrant-Whyte

Hugh Durrant-Whyte is a Professor, ARC Federation Fellow and Director of the Centre for Translational Data Science at the University of Sydney. From 2010-2014, he was CEO of National ICT Australia (NICTA), and from 1995-2010 Director of the ARC Centre of Excellence for Autonomous Systems and of the Australian Centre for Field Robotics (ACFR). He has published over 350 research papers and founded four successful start-up companies. He has won numerous awards and prizes for his work, including being named the 2010 NSW Scientist of the Year. He is an honorary fellow of the Institute of Engineers Australia (HonFIEAus), a fellow of the IEEE (FIEEE), of the Academy of Technological Sciences (FTSE), of the Australian Academy of Science (FAA), and of the Royal Society of London (FRS).

Keynote Presentation 2: Green Vehicle Routing

By Prof. Gilbert Laporte

In green vehicle routing the aim is to design vehicle routes while trying to minimize polluting emissions. This is done by minimizing fuel consumption which mostly depends, in a non-linear fashion, on speed, load and distance traveled. In this talk I will first describe the speed optimization problem on a fixed route, which was first developed in a maritime transportation context. I will then describe the pollution-routing problem first proposed by Bektas and Laporte in a Transportation Research, Part B article in 2011.

Finally, I will provide a brief overview of several projects that were carried out in recent years after the publication of the pollution-routing article. These concern the development of heuristics for several variants of the pollution-routing problem, an application to city logistics, and an emerging line of research on the use of electric vehicles for goods transportation.

About Prof. Gilbert Laporte

Gilbert Laporte obtained his Ph.D. in Operations Research at the London School of Economics in 1975. He is Professor of Operations Research at HEC Montreal, Canada Research Chair in Distribution Management, and adjunct Professor at Molde University College, the University of Bilkent, the University of Alberta and Universite Laval. He is also a member of the Interuniversity Research Centre on Enterprise Networks, Logistics and Transportation (CIRRELT) and founding member of the Groupe d'etudes et de recherche en analyse des decisions (GERAD). He has authored or coauthored 15 books, as well as more than 350 scientific articles in combinatorial optimization, mostly in the areas of vehicle routing, location and timetabling. He has received many scientific awards including the Pergamon Prize (United Kingdom) in 1987, the 1994 Merit Award of the Canadian Operational Research Society, the CORS Practice Prize on two occasions. In 1999, he obtained the ACFAS Jacques-Rousseau Prize for Interdisciplinarity, and the President's Medal (Operational Research Society, United Kingdom). In 2001, he was awarded the Pedagogy Prize by HEC Montreal. He has been a member of the Royal Society of Canada since 1998, and Fellow of INFORMS since 2005. In 2007 he received the Innis-Gerin medal from the Royal Society of Canada. In 2009 he was awarded the Gerard-Parizeau Prize, he was inducted as the 42nd Honorary Member of the INFORMS International Omega Rho Society, and he received the Robert M. Herman Lifetime Achievement Award in Transportation Science from the Transportation Science and Logistics Society of INFORMS.

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08 Industry Panels

Industry Panel 1: Stakeholder Industrial Panel

Chair: Peter Creeden from Hamburg Süd

Peter Creeden joined Hamburg Süd USA (then known as Columbus Line USA) in 1997 as an equipment control coordinator for New York and Boston. After working for Hamburg Sud in Hamburg, Germany and Miami, USA, Peter was appointed the Regional Logistics Manager for Hamburg Süd Australia in 2004. As Regional Logistics Manager for Hamburg Süd Australia, Peter was responsible for all Hamburg Süd logistics activities in Australia, New Zealand and the South Pacific. In 2011, Peter became the Managing Director Finance & Operations for Australia New Zealand. Prior to joining Hamburg Süd, Peter graduated from Texas A&M University at Galveston (Texas Maritime Academy) with a Bachelors of Science in Maritime Administration.

Industry Panel 2: Supply Chain Industrial Panel

Chair: Dr. Thomas Vitsounis from Data 61

Thomas holds a PhD in port economics and management with vast experience as a senior ports and maritime transport and logistics expert. He has proven success managing transformational ICT and other improvement projects for public, private, and international port/maritime organizations. Thomas established a new business stream from scratch for NICTA's (now Data61) business teams focused on ports, shipping and freight supply chains across the Asia Pacific region. He advised the Secretary General for Ports and Ports Policy in Greece, held a key role on a major port performance management project (PPRISM) in Europe, and lectured Maritime Economics, International Maritime Policy, Port Planning & Policy, Port Management and European Port Policy at under-graduate and post-graduate level. He is a founding member of Porteconomics.eu, a web-based initiative advancing knowledge exchange in port economics, management & policies. Thomas is currently the business leader for ports, shipping and freight in Data61 (CSIRO's Digital Productivity business unit and NICTA have joined forces to create digital powerhouse Data61).

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09 Tutorials

Tutorial 1 – Port Operations and Economics

By Dr. Xiaowen Fu

Dr Xiaowen Fu joined the Institute of Transport and Logistics Studies as Senior Lecturer in Ports and Maritime in April 2013. Prior to this, he was Associate Professor at the Faculty of Business, Hong Kong Polytechnic University. He obtained his PhD degree from the Sauder School of Business, University of British Columbia in Canada in 2006. His main research area is transport economics which covers issues such as competition policy and government regulation, efficiency benchmarking, transport demand modelling and industrial organisation. Most of Dr Fu's studies are related to the aviation industry and the maritime industry. Xiaowen has provided advisory and economic modelling services to organisations such as the Boeing Commercial Aircrafts, New Zealand Commerce Commission, Australian Competition and Consumer Commission, Australian Competition Tribunal, Civil Aviation Administration of China, Hong Kong Central Policy Unit and Japan Rail (East). He is also a co-author for the key background report to the 2009 OECD Transport Ministerial Conference.

Tutorial 2 – Container Line Network Design

By Prof. Rommert Dekker

Rommert Dekker is a full professor of Operations Research and Quantitative Logistics at the Erasmus School of Economics, at the Erasmus University Rotterdam. His research interests are port and container logistics, reverse and green logistics and spare parts management. He has published some 100 papers in ISI journals, including Management Science, Transportation Science, Production Operations Management journal, the European Journal on Operational Research, Decision Sciences etc. He is involved in several industry related projects, on service logistics and on intermodal transport and large container ships.

Tutorial 3 – Cargo Routing and Empty Container Repositioning

By Dr. Panagiotis Angeloudis

Dr Panagiotis Angeloudis is Lecturer in Engineering Systems & Logistics at the Dept. of Civil & Environmental Engineering at Imperial College London and Director of the Port Operations Research and Technology Centre (PORTeC) within the Centre for Transport Studies. His work to date has spanned the areas of network optimisation, urban transport systems, logistics and maritime transport. Previously Panagiotis was a JSPS Fellow at Kyoto University. Panagiotis obtained his PhD in Transport and MEng in Civil & Environmental Engineering from Imperial.

Tutorial 4 – Operation Scheduling at Container Terminals

By Prof. Kap Hwan Kim

Kap Hwan Kim is working at the Department of Industrial Engineering of Pusan National University. He has studies at Seoul National University (Bachelor, 1977) and Korea Advanced Institute of Science and Technology (Master, 1979; Ph.D., 1987). He was a visiting scholar at Purdue University (1990-1991), Montreal University (2002-2003), and Shanghai Maritime University (2010). He was the president of Korean Institute of Industrial Engineers. His research has been focused on the design and operation problems of container terminals and published many papers related to the design and operation of container terminals at various international journals. He organized many international conferences such as International Conference on Logistics and Maritime Systems (LOGMS), International Conference on Intelligent Manufacturing and Logistics (IML), and International Conference on Intelligent Logistics Systems (ILS).

10 Extended Abstracts

13:30 – 15:30	Session 1A (Floor 17)	Chair: Chung-Yee Lee
	Theme: Logistics (Bullwhip effects, data and Industrial logistics)	

The Bullwhip Effect of Make-to-Order Manufactures that Consider Rush Order in Two-Stage Decentralized Supply Chain Systems
Yufang Chiu, Chen-An Ma and He-Hsuan Hsu

Industrial Logistic Performance Evaluation: A Case of Bulk Feed Truck Manufacturing Company in Thailand
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Data Driven Newsvendor Problem
Renrong Weng, Javier Loh, Giulia Pedrielli and Loo Hay Lee

Empirical Investigation of Supply Chain Structure using Network Theory
Supun Perera, Mahendrarajah Piraveenan, Michael Bell and Michiel Bliemer

The Bullwhip Effect of Make-to-Order Manufactures that Consider Rush Order in Two-Stage Decentralized Supply Chain Systems

Yufang Chiu[1*], *Chen-An Ma*[2], *He-Hsuan Hsu*[3]

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1. Introduction

Under the globalized competition, enterprises have considered how to reduce the costs with maintaining consistent service level effectively, and a good inventory management is an important factor. Lee et al (1997a, b) indicated that the bullwhip effect is one of the main reasons that increases the inventory level in a supply chain. Although the problem of bullwhip effect has also been studied by many scholars, the research that incorporating the bullwhip effect and MTO (Make To Order) production was very little (Sahin and Robinson, 2005). Dejonckheere et al (2003) mentioned that the bullwhip effect will be reduced if the retailer reduces the ordering quantities, but it will increase retailer's costs and safety stock. Bray and Mendelson (2015) believed the bullwhip effect and production smoothing look opposing and investigated the production smoothing measure with a scheduling model. Niranjan et al (2011) incorporated two aspects of bullwhip effects – enlargement of order variance and schedule unsteadiness and presented a comprehensive model to measure the bullwhip effect.

Most studies only investigated the bullwhip effect and rush orders seperately, but few scholars studied the supply chain model that integrates rush order in bullwhip effect analysis. Therefore, this research studies the bullwhip effect and rush order in make-to-order production; the purpose of this study is to build a single retailer and single manufacturer decentralized supply chains that integrate rush orders. The retailer adopts smoothing period replenishment strategies in this model, and make-to-order manufacturers will adopt periodic rescheduling and continuous rescheduling to solve the problem caused by rush orders. This study thus investigated the performance of bullwhip effect and different rescheduling strategies.

2. Model Construction

This study referes to the study of Boute et al (2007b) that proposed a decentralized supply chain model that contains a single retailer using smoothing replenishment strategies and a single MTO manufacturer. To make this model close to reality, the study will also refer to the study of Aldowaisan and Allahverdi (1998) which proposed the production scheduling model of no-wait two machine flow shops with separated setup times, then integrate rescheduling strategies by Vieira et al (2000) with the method of completely rescheduling by Sawik (2007) to manage the rush order problem.

Therefore, this study extended the model of Aldowaisan and Allahverdi (1998) to the rescheduling model of two machines in no-wait flowshops with separated setup times, as follows:

Minimize

$$Tl_s = \sum_{j=1}^{sw} l_{s,j} = \sum_{j=1}^{sw} \max\left(0,\ CT_{s,j} - \theta p_{s,j}\right)$$

Subject to

$$CT_{s,j} = \max\begin{Bmatrix} CT_{s-1,sw}\cdot z_{s,j} + CT_{s,j-1}\cdot\left(1-z_{s,j}\right) + ST_{[s,j],2}\ , \\ CT_{s-1,sw}\cdot z_{s,j} + CT_{s,j-1}\cdot\left(1-z_{s,j}\right) + ST_{[s,j],1} \\ + PT_{[s,j],1} - PT_{[s,j-1],2} \end{Bmatrix} + PT_{[s,j],2} \quad (1)$$

$$ST_{[s,j],k} = \frac{Op_{[s,j]}}{h_k} \quad (2)$$

$$PT_{[s,j],k} = \frac{Op_{[s,j]}}{m_k} \quad (3)$$

$$s = \begin{cases} s+1, & y_i = 1 \\ s\ , & y_i = 0 \end{cases} \quad (4)$$

$$z_{s,j} = \begin{cases} 1, & j = 1 \\ 0, & j = Otherw \end{cases} \quad (5)$$

$$TL_{s,j} = \left| CT_{s,j} - ap_{s,j} \right| \quad (6)$$

$$\forall \quad \left(a_i,\ O_i,\ \theta_i\right) \in RJ_i,\ \left(ar_t,\ Or_t,\ \theta r_t\right) \in r_t \ \Leftrightarrow\ \left(ap_{s,j},\ Op_{s,j},\ \theta p_{s,j}\right) \in PJ_{s,j}$$

$$CT_{-1,0} = 1.\quad PT_{[0,-1],k} = 0.\quad PT_{[s,-1],k} = PT_{[s-1,sw],k}\ .\quad when\ i = 1 \Rightarrow s = 0$$

$$i = 1,\ 2,\ \ldots,\ n.\qquad j = 1,\ 2,\ \ldots,\ sw.\qquad k = 1,\ 2.\qquad s = 1,\ 2,\ \ldots,\ g.$$

In Equation (1), $CT_{s-1,sw}$ is the completion time of finished orders sw in the $s-1^{th}$ phase. In Equation (2), h_k is setup rate in machine k. In Equation (3), m_k is capability in machine k. In Equation (4), y_i is variable that determine whether or not resecheduling is need in the end of period. The Equation (5) is determine formulation which determine whether is 1 in currently. In Equation (6), $TL_{s,j}$ is the production time of order $PJ_{s,j}$, because this study does not consider lead time in transportation, thus also become replenishment lead time of retailer's replenishment order RJ_i.

3. Research hypotheses

This study proposed two research hypotheses:

1. Hpothesis 1:

There are two models to be investigated, in hypothesis 1, model 1 is "the supply chain model does not consider rush order, that means the number of external order is 0" , and model 2 is "the supply chain model of this study integrates rush order" . The null hypothesis and the alternative hypothesis can be expressed as follows:

H_0: The safety stock of model 1 is larger or equal to that of model 2 under identical β

H_1: The safety stock of model 1 is smaller than that of model 2 under identical β

2. Hypothesis 2:

There are two models to be investigated, in hypothesis 2, model 1 is "the supply chain model of MTO manufacturer uses continuous rescheduling strategy", and model 2 is " the supply chain model of MTO manufacturer uses periodic rescheduling strategy". The null hypothesis and the alternative hypothesis can be expressed as follows:

H_0: The safety stock of model 1 is larger or equal to that of model 2 under identical β

H_1: The safety stock of model 1 is smaller than that of model 2 under identical β

4. Conclusion

This study proves that regardless of quantity of rush order and the manufacturer's continuous or periodic rescheduling strategies, the bullwhip effect can be reduced in supply chain by incorporating rescheduling strategies; meanwhile, the safety stock of retailer can also be redced to satisfy 95% of service level without huge amount of safety stock, if retailer uses smoothing replenishment strategy to reduce order quantity after considered the problem of rush order in model. That is also a win-win situation for retailer and manufacturer without coordination strategy. In addition, when there is a large quantity of external order, whether under the strategy of continuous or periodic rescheduling, the curve of safety stock will be larger than that in the supply chain model that doesn't consider rush order under the same smoothing parameter. Furthermore, the safety stock by using continuous rescheduling strategy is smaller than that by using periodic rescheduling strategy, after the decentralized supply chain between a single retailer and a single MTO manufacturer that considers problem of rush order. Because rush order is unexpected, so it will be able to reduce shortage of retailer if manufacturer use continuous rescheduling strategies to deal with problem of rush order. In addition, it reduces the average lead time of replenishment and the total delay time of order of retailer effectively through rescheduling with low frequency only when the production capacity is low under the periodic rescheduling strategy. But no matter what the production capacity is, the variance of replenishment lead time of retailer and total delay time of external order will be increased by the rescheduling strategy with low frequency, and increasing the variance of lead time is also the main reason for increasing safety stock. Thus, the manufacturer should attempt to reduce variance of replenishment lead time of retailer to avoid huge amount of shortage for retailer when the unexpected rush order arrives.

This study discussed problems only in model of decentralized supply chain between a single retailer and a single MTO manufacturer. In the future, the model will conform to actual situation by considering multiple retailers and MTO manufacturers. And the model will conform to actual situation by using forecasting techniques in future.

References

T Aldowaisan and A Allahverdi (1998) Total flowtime in no-wait flowshops with separated setup times, *Computers Ops Res*, **25**(9), 757-765.

R N Boute, S M Disney, M R Lambrecht and B V Houdt (2007b) An integrated production and inventory model to dampen upstream demand variability in the supply chain, *European Journal of Operational Research*, **178**(1), 121-142.

R L Bray and H Mendelson (2015) Production smoothing and the bullwhip effect, *Manufacturing and Service Operations Management*, **17**(2), 208-220.

J S Dejonckheere, M Disney, M R Lambrecht and D R Towill (2003) Measuring and avoiding the bullwhip effect: A control theoretic approach, *European Journal Of Operational Research*, **147**(3), 567-590.

H L Lee, V Padmanabhan and S Whang (1997a) The bullwhip effect in supply chains, *MIT Sloan Manage Rev*, **38**(3), 93-102.

H L Lee, V Padmanabhan, and S Whang (1997b) Information distortion in supply chain: the bullwhip effect, *Management Science*, **43**(4), 546-558.

T T Niranjan, S M Wagner and V Aggarwal (2011) Measuring information distortion in real-world supply chains, *International Journal of Production Research*, **49**(11), 3343-3362.

F Sahin and E P J Robinson (2005) Information sharing and coordination in make-to-order supply chains, *Journal of Operations Management*, **23**(6), 579-598.

T Sawik (2007) Integer programming approach to reactive scheduling in make-to-order manufacturing, *Mathematical and Computer Modelling*, **46**(11-12), 1373-1387.

G E Vieira, J W Herrmann and E Lin (2000) Analytical models to predict the performance of a single-machine system under periodic and event-driven rescheduling strategies, *International Journal of Production Research*, **38**(8), 1899-1915.

Industrial Logistic Performance Evaluation: A Case of Bulk Feed Truck Manufacturing Company in Thailand

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1. Introduction

Logistic performance is one of several key pillars reflecting the economic growth and competitiveness. Namely, efficient logistics contributes to reduction in the costs of trading and increase in the potential for global integration. They have been informed through the logistics performance indicators (LPIs) in areas of customs, infrastructure, services quality, international shipments, tracking and tracing, and timeliness. The LPI results in 2014 point to Germany as the best performing country with its LPI score of 4.12, whereas Somalia as the worst with 1.77 (on a scale of 1 to 5). Compared to ASEAN countries' logistic performance, Thailand is ranked at 35th with its LPI score of 3.43. It is poorer than Singapore (ranked at 5th with 4.00) and Malaysia (ranked at 25th with 3.59) as shown in Figure 1 (The World Bank organization, 2014). Such the rankings imply that Thailand requires more improvement of logistic performance in order to enhance the economic growth and competitiveness. They are significantly influenced by the industrial sector. However, the traditional LPIs is incapable of quantitatively evaluating industrial logistic performance. Banomyong and Supatn (2011) hence developed Thailand LPIs for industrial and quantitative evaluation (ILPIs).

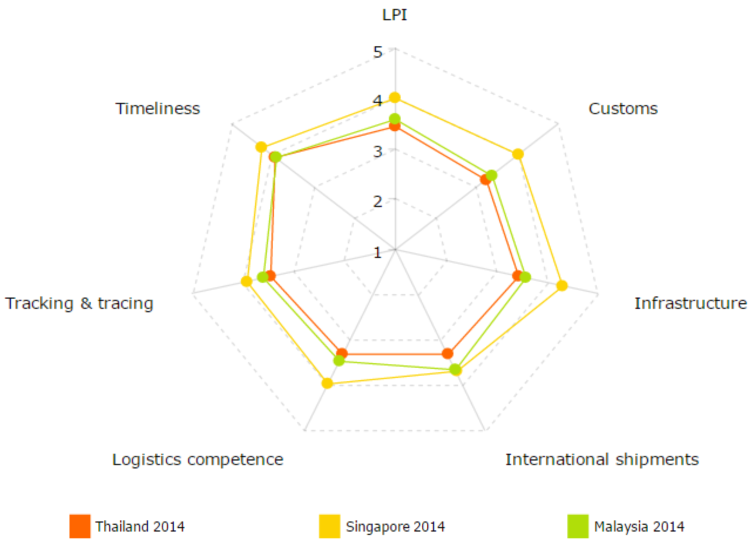

Figure 1. Global LPIs in 2014

With their capability, the ILPIs are measured in three dimensions (i.e. cost, time, and reliability) which bridge the gap of previous researches. Most of them emphasize the dimension of cost (Elmaraghy and Mahmoudi, 2009; Jaegler and Burlat, 2012) along with either the dimension of time (You and Grossmann, 2008; Boonsothonsatit et al., 2015) or the dimension of reliability (Jone et al., 2010). In addition, the ILPIs rely on the nine activities of Grant et al. (2006). These generate 27 ILPIs whose 9 ILPIs are considered as primary. They cover more than 80% of cost, time, and reliability along the logistics activities as shown in Table 1 (Banomyong and Supatn, 2011). Accordingly, this paper aims to quantitatively evaluate logistic performance with 9 primary indicators. They are successfully validated in a case of bulk feed truck manufacturing company in Thailand.

2. Methodology

In order to evaluate logistics performance with 9 primary indicators for a case of bulk feed truck manufacturing company in Thailand, its methodology undergoes four steps as follows (Figure 2). Firstly, the ILPIs is understood clearly before formulated into mathematical equations as the second step. Their data is thirdly collected from the bulk feed truck manufacturing company to input into http://lpi.dpim.go.th/frontend/ (Logistics service information center, 2010). It is a mathematical equation-embedded website for returning ILPI outputs. They are eventually resulted and discussed.

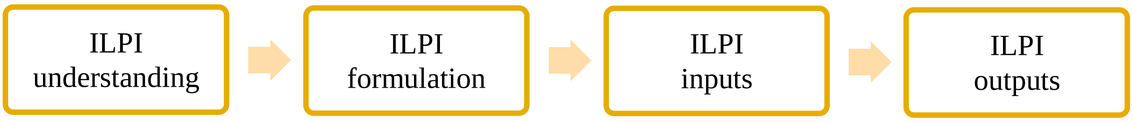

Figure 2: Four-step methodology

2.1 ILPI understanding and formulation

In order to understand the 9 ILPIs, their individuals are clarified in terms of definitions. They enable to formulate the 9 ILPIs into 9 mathematical equations which are expressed in (1) to (9) as shown in Table 1 (Banomyong and Supatn, 2011).

Table 1 : Definitions and equations of industrial ILPIs

ILPI		Definition	Equation	
ILPI8C	Transportation cost per sales	Cost incurred by inbound and outbound transportation in terms of in-house and outsourcing	If in-house, (Transportation-related workforce cost + Transportation-related fuel expense + Vehicle-related maintenance cost + Others) / Sales If outsourcing, (Inbound transportation cost + Outbound transportation cost) / Sales	(1)
ILPI6C	Warehousing cost per sales	Cost incurred by warehouse, material handling, and warehouse management system (WMS) in terms of in-house and outsourcing	If in-house, (Depreciated value of warehouse + Insurance cost of warehouse + Warehouse-related workforce cost + Depreciated value (or rental) of material handling + Material handling-related workforce cost + Depreciated value (or rental) of WMS + Others) / Sales If outsourcing, (Warehouse area x Warehouse rental) / Sales	(2)
ILPI7C	Inventory carrying cost per sales	Opportunity cost incurred by material, work in process (WIP) and finished good holding	(Inventory carrying cost + Inventory insurance) x (1 + MRR) / Sales	(3)

ILPI		Definition	Equation	
ILPI2T	Average order cycle time	A period of time since customer orders are received until arrived to customer	Constant	(4)
ILPI8T	Average delivery cycle time	A period of time since customer orders are loaded on the vehicle until arrived to customer	Constant	(5)
ILPI7T	Average inventory day	A period of time that inventory is used up	365 / (Sales / Inventory carrying cost)	(6)
ILPI8R	Transportation DIFOT rate	Percentage of (customer) orders delivered in full and on time	(Number of orders delivered in full / Number of orders delivered) * (Number of orders delivered on time / Number of orders delivered)	(7)
ILPI1R	Forecast accuracy rate	Accuracy of forecasting (customer) orders when compared with actual orders	1- | Number of actual order - Number of forecasted order | / Number of actual order	(8)
ILPI9R	Rate of return goods	Proportion of poor-quality goods e.g. damaged, misplaced, broken, and expired items	Number of returned goods / Number of delivered goods	(9)

2.2 ILPI inputs and outputs

According to the mathematical equations of 9 ILPIs, their related parameters are collected from a case of bulk feed truck manufacturing company in Thailand. The collected parameters are input into http://lpi.dpim.go.th/frontend/ (Logistics service information centre, 2010) which embeds the mathematical equations of 9 ILPIs. The mathematical equation-embedded website returns a spider chart and nine bar charts as outputs. The spider chart contains the scores of individual 9 ILPIs. They are scaled from 1 (poor) to 5 (excellent) by benchmarks among other companies having the same international standard industrial classification of all economic activities (ISIC) as shown in Figure 3.

3. Result and discussion

A case of bulk feed truck manufacturing company in Thailand is studied as a small-sized production business. It initially registered capital of 1 million Thai Baht (THB), and currently manufactures bulk feed truck products which are coded with ISIC of 2920. Benchmarked among other companies having the same ISIC in year 2014, the case study is competitive in terms of cost (i.e. ILPI7C and ILPI8C) and reliability (i.e. ILPI8R and ILPI9R) as shown in Figure 3. However, the case study confronts of poor forecast accuracy rate (ILPI1R) and long average order cycle time (ILPI2T). Such the poor LPIs absolutely require urgent improvements. ILPI1R can be improved by adopting enterprise resource planning (ERP). It connects all of front-end, engine, and back-end and enables to demand-driven planning and control. The ILPI1R improvement is an important enabler to shorten ILPI2T and upgrade others.

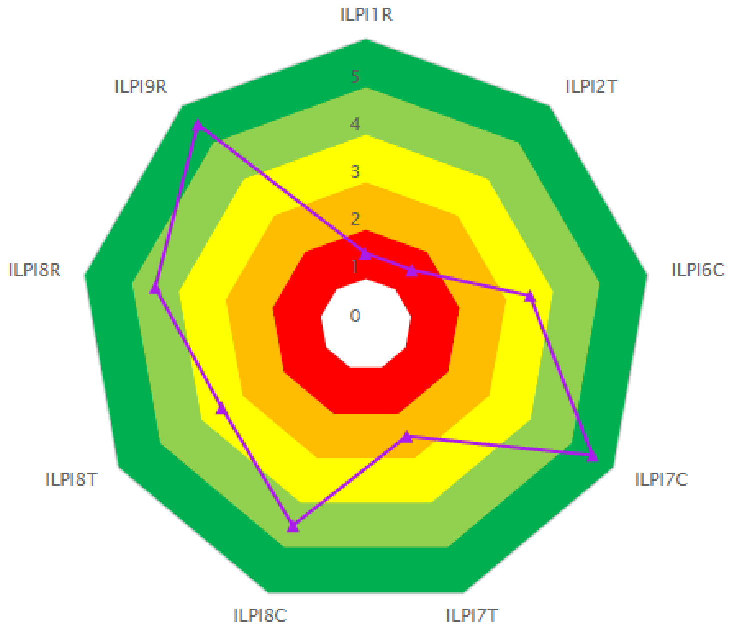

Figure 3: ILPI results

4. Conclusions

This paper proposes the nine logistic performance indicators (9 ILPIs) developed by Banomyong and Supatn (2011). They are superior to the ILPIs of the World Bank organization (2014) in terms of industrial and quantitative evaluation. The 9 ILPIs are hence applied for continuous improvements in a case of printing and packaging company in Thailand. It is found that the individual ILPIs are interrelated. In other words, a change of one ILPI has effects on other ILPIs. The effects can be positive and negative, direct and indirect. However, the 9 ILPIs of Banomyong and Supatn (2011) are incapable of indicating such the ILPI interrelations. This is recommended as a future study.

References

A Jaegler and P Burlat (2012) Carbon friendly supply chains: A simulation study of different scenarios, *Production Planning and Control*, **23**, 269-278

B Grant, M Lambert, R Stock and M Ellram (2006) *Fundamentals of Logistics Management*, McGraw-Hill, Maidenhead

E C Jones, R B Franca, C N Richards and J P Carlson (2010) Multi-objective stochastic supply chain modeling to evaluate tradeoffs between profit and quality, *International Journal of Production Economics*, **127**, 292-299

F You and I E Grossmann (2008), Design of responsive supply chains under demand uncertainty, *Computers and Chemical Engineering*, **32**, 3090-3111

H A Elmaraghy and N Mahmoudi (2009) Concurrent design of product modules structure and global supply chain configurations, *International Journal of Computer Integrated Manufacturing*, **22**, 483-493

K Boonsothonsatit, S Kara, S Ibbotson and B Kayis (2015) Development of a Generic decision support system based on multi-Objective Optimisation for Green supply chain network design (GOOG), *Journal of Manufacturing Technology Management*, **26**(7), 1069-1084

Logistics service information center (2010) *Industrial performance index*

R Banomyong and N Supatn (2011) Developing a supply chain performance tool for SMEs in Thailand, *Supply Chain Management: An International Journal*, **16**(1), 20-31

The World Bank organization (2014) The logistics performance index and its indicators, 47-50

DATA DRIVEN
OPTIMAL NEWSVENDOR PROBLEM

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1. Introduction

The Newsvendor problem is the traditional inventory problem of determining how many copies of newspaper to order in the face of stochastic and unknown demand. In the typical form of the problem, a one-stage Newsvendor model is established to find the optimal stock level for maximizing its expected profit, based on the assumption that the demand distribution is known in advance. However, practitioners criticize that only a time series of sales data rather than the demand distribution is available in reality. Hence, a data driven analysis is desired to facilitate newspaper demand forecast and newspaper delivery decision-making. In particular, in the data analysis, several critical properties of the sales time series should be considered.

1. The sales time series data possesses an autocorrelation relationship.
2. The daily sale is the minimum of the true demand and the supplied copies, i.e., the time series data records the censored demand rather than the true demand.
3. The sales time series data is more often than not non-stationary, especially in the long term.
4. The sales time series data exhibits an evident seasonality.
5. There are some outliers in the time series, due to the surge demand in public holiday and some days with special events.

To resolve all of the aforementioned criticalities, we develop a Censored-Auto Regressive Integrated Moving Average (C-ARIMA) framework to predict newspaper demand and decide the copies of newspaper to order. In the proposed framework, we first remove the outliers using stochastic process control tool, followed by de-trending from the sales time series to get a relatively stationary time series. Furthermore, we propose an augmentation algorithm to adjust the censored demand to estimate the real demand. With the augmented time series, we apply Auto Regressive Integrated Moving Average (ARIMA) model to predict demand and distribute newspapers. In the numerical experiments, we use a realistic case thanks to the collaboration of one of the main news companies in Singapore. Two quantitative metrics regarding potential increasing revenue and availability, which is defined as the percentage of stores with at least one copy left at the end of the day, are proposed to evaluate the performance of our method and the approach currently adopted by the company. The results are promising and they indicate a substantial benefit of the proposed approach, especially in the reduction of the variability of the outcome.
The remaining sections will be arranged as follows: Section 2 will outline the methodology, while Section 3 shares the preliminary result and the last section will conclude the paper.

2. Methodology

In order to achieve a relevant improvement for the company, we went through a detailed data analysis which had both the objective to understand characteristics of the sales and the newspaper demand as well as the cleaning of the data.
Subsequently a procedure to derive demand forecast was proposed and the resulting model used to design a new allocation policy for the company. The following sections go briefly through the main aspects of the three phases.

2.1 Data Analysis

The company provided us with historical newspaper sales data for 5 consecutive years in several outlet stores in the city. In addition, the data set contains details of the retail outlets such as the geographical location and the building description of outlet (eg. Office , underground Station/ Depot, etc).
We categorised he geographical locations will be categorised into mature and non-mature estates as defined while the building descriptions are grouped according to the land use zoning by Urban Redevelopment Authority of Singapore.
Analysing the data, we observed a decreasing trend in yearly average newspaper sales over the years from 2012 to 2014. This could be due to consumers shifting over to online subscription. However, the results were not statistically significant to conclude that the yearly average sales are different across the years.
On the contrary, it looked apparent the presence of a clear daily seasonality indicating that newspaper sales for each day of the week come from different distributions and need to be accounted for during model development.

2.2 Demand Forecasting Model

This section will focus on developing a Censored-Auto-Regressive Integrated Moving Average (C-ARIMA) model to deal with all of the aforementioned properties accordingly. Among these properties, censored demand seems to be the most critical one as the sales data is always biased due to the censoring nature. Models based on the sales data will lead to an under-estimated result. In addition, we will also cover on the distribution policy which takes in the output from the demand forecasting model.
We propose a *rolling horizon prediction method*, and we provide the flexibility of using T days (in the numerical section, we use T = 180 days) from the historical time series data for demand model calibration as well as prediction for the following week. We will then move forward by one week and proceed in a rolling horizon manner. The value of T is selected in a way that strikes a balance between practicality and relevance. Too many data points result in long computational time which may not translate to increased information for demand prediction. On the other hand, insufficient data points may result in over fitting of model (i.e. the statistical model describes random noise rather than the underlying relationship).

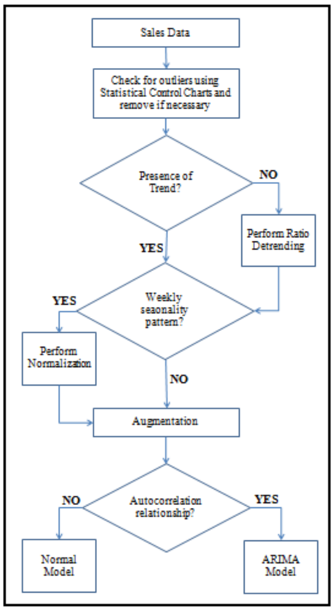

Figure 1: Flow chart for the methodology

The flowchart in Figure 1 describes the steps for model estimation. The first step involves the preprocessing of data. Outliers in the time series sales data are removed using statistical process control tool while trend and seasonality components are treated using ratio-detrending and normalization. In the second step, the augmentation algorithm will be applied to deal with the censored data. Finally, we will perform the prediction and obtain the demand forecast using a normal or ARIMA model, depending on the autocorrelation relationship in the time series sales data. Refer to Figure 2 for an overview of the different demand forecasting models used for outlets with varied properties.

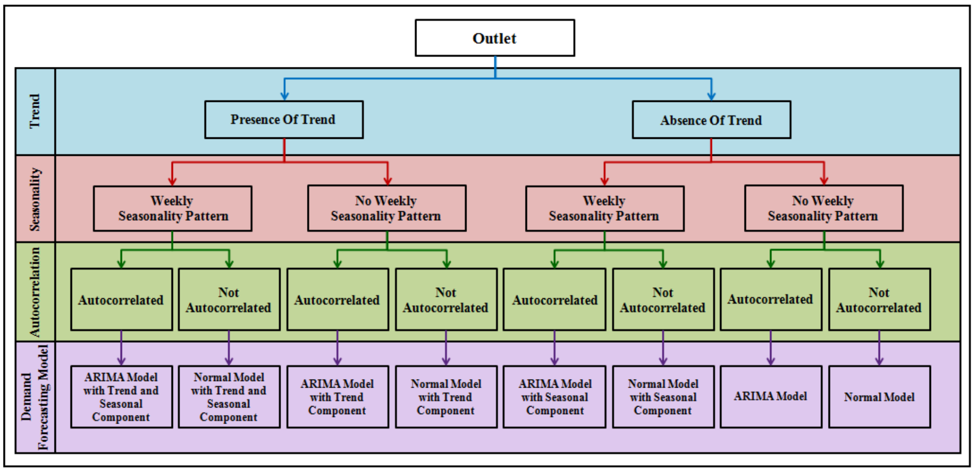

Figure 2: Demand Forecasting Models for Outlets with Varied Properties

A fundamental step of the proposed procedure was the augmentation of the data provided by the company. Indeed the data are sales data and not demand data. As a result, we need to consider that when the sales information is disclosed and there is no inventory left, the demand value has been censored and the forecasting model should consider this aspect. In order to do so, we model de de-seasonalized and de-trended data using a Censored ARMA process. We consider a censored time series $\mathbf{X} = (X_1, X_2, \ldots, X_n)$ and the corresponding underlying true process $\mathbf{Y} = (Y_1, Y_2, \ldots, Y_n)$. Assume that $\mathbf{Y}$ is an realization from a stationary stochastic process described by an ARMA(p, q) model with Gaussian white noise. In other words,

$$\mathbf{Y} \sim N_n(\mu, \Sigma)$$

Where we denote by $N_n(\mu, \Sigma)$ an n-dimensional multivariate normal distribution with mean μ and covariance matrix Σ. We can rearrange these two time series by partitioning them into an observed part $\mathbf{X_O}$, $\mathbf{Y_O}$ and a censored part $\mathbf{X_C}$, $\mathbf{Y_C}$ using a permutation matrix $\mathbf{P}$. Namely, we have

$$\mathbf{PX} = \begin{bmatrix} \mathbf{P_O} \\ \mathbf{P_C} \end{bmatrix} \mathbf{X} = \begin{bmatrix} \mathbf{X_O} \\ \mathbf{X_C} \end{bmatrix}$$

$$\mathbf{PY} = \begin{bmatrix} \mathbf{P_O} \\ \mathbf{P_C} \end{bmatrix} \mathbf{Y} = \begin{bmatrix} \mathbf{Y_O} \\ \mathbf{Y_C} \end{bmatrix}$$

Where all the components in the array of $\mathbf{P_O}$ is 1 and all the components in the array of $\mathbf{P_C}$ is 0. It thus follows by the censoring mechanism that $\mathbf{X_O} = \mathbf{Y_O}$ and $\mathbf{Y_C} \geq \mathbf{X_C}$. In particular, the permuted time series $\mathbf{PY}$ follows a multivariate normal distribution given by the following:

$$\mathbf{PY} \sim \mathbf{N_n}\left(\begin{bmatrix} \mathbf{P_O} \\ \mathbf{P_C} \end{bmatrix} \boldsymbol{\mu}, \begin{bmatrix} \Sigma_{OC} & \Sigma_{OC} \\ \Sigma_{CO} & \Sigma_{CC} \end{bmatrix} = \begin{bmatrix} \mathbf{P_O}\Sigma\mathbf{P_O^T} & \mathbf{P_O}\Sigma\mathbf{P_C^T} \\ \mathbf{P_C}\Sigma\mathbf{P_O^T} & \mathbf{P_C}\Sigma\mathbf{P_C^T} \end{bmatrix} \right) \tag{7}$$

where the superscript $\mathbf{T}$ represents transpose operation. Referring to Anderson (1958), it follows that $\mathbf{Y_C}$ conditional on $\mathbf{Y_O}$ is still normally distributed. Its mean and covariance matrix are functions of the observed array $\mathbf{Y_O}$ and unknown parameters $\boldsymbol{\mu}$ and Σ. Accordingly, the distribution of $\mathbf{Y_C}$ given $\mathbf{X_O}$ and $\mathbf{Y_C} \geq \mathbf{X_C}$ is a n_c dimensional multivariate truncated normal distribution where n_c is the number of censored observations in the time series. The basic idea of the proposed augmentation algorithm is then to replace the censored observations $\mathbf{X_C}$ with sampling values from the truncated normal distribution $\mathbf{Y_C}|\mathbf{X_O}, \mathbf{Y_C} \geq \mathbf{X_C}$ using MCMC sampling approach (Gelfand and Smith, 1990). Now, let $g(\mathbf{x})$ be the density function of $\mathbf{Y_C}|\mathbf{X_O}$ defined on the n_c dimensional Euclidean space, Where $\mathbf{x} = (x_1, x_2, \ldots, x_{n_c})$. We also denote the truncated space by $A = \otimes_{j=1}^{n_c} A_j$ where $A_j = [c_j, +\infty]$ and c_j is the censored level for the j^{th} observation. Thus, the density function $f(x)$ of truncated normal distribution $\mathbf{Y_C}|\mathbf{X_O}, \mathbf{Y_C} \geq \mathbf{X_C}$ can be represented by:

$$f(x) = \frac{g(x) I_A(x)}{\int_A g(z)\, dz}$$

We can then use this density for augmenting the data through a simple MCMC algorithm.

2.3 Allocation Policy

The number of newspaper copies to be allocated to outlets will be the predicted demand with additional adjustments depending on their respective variability. This is because the prediction resulting from the model in the previous section is the expected demand and allocating sorely on the average demand will result in the outlet being out-of-stock about 50% of the time. If the normal distribution model with trend and seasonal components is used when predicting the newspaper demand, the number of newspaper copies to be distributed for day $T+\tau$:

$$Q = \widehat{D}_{T+\tau} + r_{m_{T+\tau}}\left[\sigma_{d_{T+\tau}}(z_{\propto}\sigma^{N})\right]$$

Where $\widehat{D}_{T+\tau}$ is the newspaper demand forecast for Day $T+\tau$, $r_{m_{T+\tau}}$ is the ratio between the monthly sales in month $m_{T+\tau}$ and the average monthly sales in the specified period. $\sigma_{d_{T+\tau}}$ is the mean and standard deviation of the observed demand for the particular day of the week $d_{T+\tau}$. $z_{\propto}$ is the quantile of the normal distribution and σ^{N} is the standard deviation of $\boldsymbol{Z^N}$, the augmented, normalized and de-trended time series used in the prediction. For the ARMA(1,1) and ARIMA(1,1,1) models, the number of newspaper copies to be distributed for Day $T+\tau$ will be adjusted by the standard error of demand forecast for Day $T+\tau$. Refer to Appendix C.1 for the summary of the demand forecasting model and distribution policy. The company considers one to be a good distribution policy if it achieves an availability of 70% - 75% daily across all outlets and minimizes the average number of returns per outlet to 1.5 - 2.5 copies daily. Having an availability of 75% across all outlets on a daily basis is not equivalent to each of the outlets having an availability of 75%. The outlet usually has an availability that is greater than 75%.

3. Preliminary Results

Given that our demand forecasting model takes in 180 days of data to predict the demand for the next 8 to 14 days, we obtained the augmented sales and allocated amount of the new policy starting from June 2014 to December 2014. Different values of $z_{\propto}$ were set to achieve a certain daily availability at a 95% confidence level. The chosen daily availabilities ranges from 65% to 95%, with a 5% interval between subsequent values. From the results we observed that, despite the expected availability does not decrease, the proposed approach leads to increase in sales, i.e., more newspapers are allocated to more profitable stores as shown in Figure

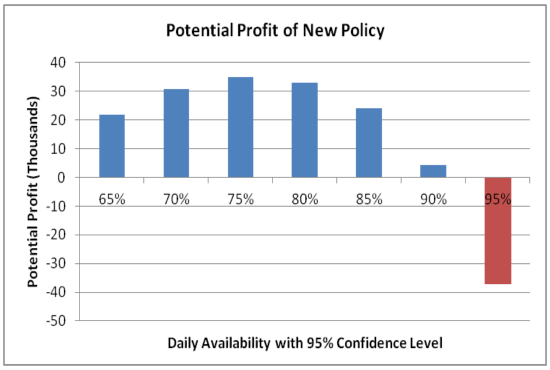

Figure 3: Potential Profit deriving from the new allocation policy

References

Gelfand, A. E., & Smith, A. F. (1990). Sampling-based approaches to calculating marginal densities. Journal of the American statistical association, 85(410), 398-409.

Empirical Investigation of Supply Chain Structures using Network Theory

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Abstract

Due to the increasingly complex and interconnected nature of the modern supply chain networks (SCNs), a recent trend of research have focussed on modelling SCNs as complex adaptive systems. Owing to the recent advances in network theory, researchers have investigated key properties of SCN topologies, arising from various generalised growth mechanisms, using established network theoretical measures. Despite the large amount of theoretical research published in the field of SCN topological analysis, there has been very limited effort on empirical validation of the theoretical findings. Accordingly, this study aims to fill this void by first analysing the topological character of a collection of SCNs, from various industries, and then comparing these findings against the theoretical predictions made in past studies in this area. In addition, the node and network level metrics, for each SCN, have been compared in order to deduce insights on various industrial sectors and their operations. Finally, the topological characteristics calculated for the various SCNs have been compared against other real world instances of complex networks, such as WWW, power grids, social networks, biological networks and air transport networks.

1. Introduction

Traditionally, supply chain operations have been modelled as multi agent systems, in order to represent explicit communications between various autonomous entities involved (Thadakamalia et al., 2004). However, due to the increasingly complex and interconnected nature of the global supply networks, owing to the recent advances in network theory, a recent trend of research has focussed on modelling supply networks as complex adaptive networks. Following on from the influential work published by Thadakamalla et al. in 2004, which utilised network theory to investigate the topological resilience of supply chain networks (SCNs), a large number of research papers have appeared in this area (Xuan et al., 2011; Zhao et al., 2011(a); Zhao et al., 2011(b); Wen and Guo, 2012; Li et al., 2013; Yi et al., 2013; Li, 2014; Mari et al., 2015 and Kim et al., 2015).

Most of these research studies have generated network topologies based on various customised growth models and have studied the topological character, such as robustness and efficiency, of the resulting networks.

By accounting for growth mechanisms, network models are able to represent dynamical and open system characteristics of real life SCNs, where nodes enter and exit the network over time (Hearnshaw and Wilson, 2013). In the context of supply networks, the concept of growth implies how firms join together to form complex SCNs. As new entrants join the supply network, it could select partners from within that particular network. This partner selection is indeed a multi-objective problem and involves numerous factors, such as price, performance, quality, goodwill, etc (Jain et al., 2009; Li et al., 2013). However, it is not practical to consider all these factors in to a single model (since the factors themselves and the weights allocated for each of the factors is subjective and may vary from one firm to another). As such, in order to overcome this obstacle, researchers have adopted a more simple yet intuitive approach. This includes considering the network from a topological perspective and specifying growth (attachment) rules based on one or more basic topological properties, such as the node degree (i.e. the connectedness of a given firm).

Examples of customised attachment rules include the Hierarchy +/Ad-Hoc attachment rules proposed by Thadakamalla et al. (2004), Degree and Locality based Attachment (DLA) rule proposed by Zhao et al. (2011), and the Randomised local rewiring (RLR) introduced by Zhao et al. (2011). Each of the aforementioned attachment rules, over time, generate networks with distinct topologies. These topological characteristics have then been compared with the known features of other network benchmark models. Broadly classified, the complex network modelling of SCNs has mainly focussed on the following network models for benchmarking purposes;

1) Random graphs (Erdös and Rényi, 1959): where vertices are randomly connected to each other.
2) Small-world networks (Watts and Strogatz, 1998): most nodes of such a network are not neighbours of one another, but most nodes can be reached from every other node by a small number of steps.
3) Scale-free (Barabási and Albert, 1999): degree distribution follows a power law, at least asymptotically.

Despite the large number of theoretical research work being published in the field of network modelling of SCNs, within the past few years, the effort on empirical validation of the conceptual findings has been limited.

In above light, through a comprehensive analysis of an empirical dataset of SCNs, this study aims to answer the following key research questions;

1. Is there a generalizable growth mechanism for modelling the emergence of SCNs through firm partnering?
2. What common characteristics (if any) can be expected from real world SCNs (based on size or sector)?
3. Do cost and time, at each stage of the SCN, correlate with any network metrics?

2. Methodology

Willems (2008) provides a dataset of real world multi echelon supply chains, used for inventory optimization purposes. The overall dataset includes a total of 38 multi echelon supply chains, from various industries, that have been implemented in practice. The chains described in this paper comprise actual supply chain models created by either company analysts or consultants. Since these models using the data have been implemented in practice, these chains demonstrate how real users have modelled their real-world supply chain situations.

Using Cytoscape software, the above mentioned SCNs have been visualised and analysed through various network and node level metrics. These metrics are summarised in the table below.

Table 1: Node and network level metrics used to characterise the SCNs

Metric	Definition
Node level	
Degree	Represents the number of direct neighbours (connections) a given node has.
Clustering coefficient	Is the ratio between the number of triangles that contain node I and the number of triangles that could possibly exist if all neighbours of I were interconnected. Measures the local cohesiveness. This property occurs with a neighbours of a node tend to make connections among themselves.
Betweenness centrality	Betweenness centrality of a node is defined as the number of shortest paths going through the node in concern, considering the shortest paths that connect any two given nodes in the network.
Closeness centrality	Closeness centrality is a measure of the time that it takes to spread the information from a particular node to the other nodes in the network. While it is closely related to betweenness centrality, closeness more relevant in situations where a node acts as a generator of information rather than a mere mediator.
Eigenvector centrality	Eigenvector centrality measures a node's influence in a network by taking into account the influence of its neighbours. It assumes that the centrality score of a node is proportional to the sum of the centrality scores of the neighbours. As such, it is defined iteratively.
Topological coefficient	The topological coefficient is a relative measure for the extent to which a node shares neighbours with other nodes. The chart of the topological coefficients indicates the tendency of the nodes in the network to have shared neighbours.
Network level	
Average degree	On average, how many connections does a given node has. Higher average degree implies good inter-connectivity among the nodes in the network.
Network diameter	The diameter of a network is the largest distance between any two nodes in the network.
Characteristic path length	The characteristic path length (L) of a network is the shortest path length between two nodes, averaged over all pairs of nodes, in the network. Higher L implies that the network is almost a linear chain and lower L indicates that the network is compact.
Network centralisation	Network centralisation provides a values for a given network between 0 (if all nodes in the network have the same connectivity) and 1 (if the network has a star topology).
Network heterogeneity	Heterogeneity is the coefficient of variation of the connectivity. Highly heterogeneous networks exhibit hubs.
Degree exponent	The degree distribution of a scale free network is approximated with power law as follows; $P(k) \sim k^{-\gamma}$ Where k is the degree of the node and γ is the degree exponent (also known as the power law or scale free exponent).

3. Results and conclusions

The preliminary analysis results for the SCNs indicate the following;

- For the majority of the SCNs, it was found that the firms which add high proportion of value to the final product, tend to be highly connected (i.e. high degree nodes).
- In general, as the amount of value added to the final product by a firm increases, its distance (in terms of contractual links) to other firms in the network tend to reduce (i.e. high value adding firms tend to have close links with other firms).

- In general, as the amount of value added to the final product by a firm increases, the amount of gatekeeping done by that particular firm tends to increase (i.e. firms with high betweenness add higher value to the final product).
- No significant correlations were found between the network metrics and the stage time at each firm in each SCN considered.
- No significant variations were observed between the SCNs of various sectors. This implies that generalising the results for various sectors is not possible, due to the large variations observed in the real world.
- Interestingly, all the SCNs analysed in this study comprise of degree exponents (γ) that lie between 0.5 – 2.0, indicating the network structure is more hub and spoke than scale free. It is known that the generalised Barabasi Albert model generates networks with degree exponents in the range of 2.0 - 3.0. Therefore, any generalizable growth model for SCN analysis should generate network topologies with degree exponents between 0.5 – 2.0.
- Since γ varies from system to system, the network properties also change with this parameter. As is evident from the empirical analysis presented in this paper, real world SCNs tend to have hubs which are more prominent than in general scale free networks. This implies that a finite number of firms retain a significant fraction of all connections – so their removal has a considerable effect on the overall network.

References

Barabási, Albert-László, & Albert, Réka. (1999). Emergence of scaling in random networks. *Science*, *286*(5439), 509-512.

Erdős, P.; Rényi, A. (1959). "On Random Graphs. I". *Publicationes Mathematicae 6*: 290–297.

Hearnshaw, E. J., & Wilson, M. M. (2013). A complex network approach to supply chain network theory. *International Journal of Operations & Production Management, 33*(4), 442-469.

Jain, V., Wadhwa, S., & Deshmukh, S. G. (2009). Select supplier-related issues in modelling a dynamic supply chain: potential, challenges and direction for future research. *International Journal of Production Research*, *47*(11), 3013-3039.

Kim, Y., Chen, Y. S., & Linderman, K. (2015). Supply network disruption and resilience: A network structural perspective. *Journal of Operations Management*, *33*, 43-59.

Li, G., Gu, Y. G., & Song, Z. H. (2013). Evolution of cooperation on heterogeneous supply networks. *International Journal of Production Research*,*51*(13), 3894-3902.

Mari, S. I., Lee, Y. H., Memon, M. S., Park, Y. S., & Kim, M. (2015). Adaptivity of Complex Network Topologies for Designing Resilient Supply Chain Networks. *International Journal of Industrial Engineering*, *22*(1), 102-116.

Thadakamalla, H. P., Raghavan, U. N., Kumara, S., & Albert, R. (2004). Survivability of multiagent-based supply networks: a topological perspective. *Intelligent Systems, IEEE*, *19*(5), 24-31.

Watts, D. J., & Strogatz, S. H. (1998). Collective dynamics of 'small-world' networks. *Nature*, *393*(6684), 440-442.

Wen, L., & Guo, M. (2012). Statistic Characteristics Analysis of Directed Supply Chain Complex Network. *International Journal of Advancements in Computing Technology*, *4*(21).

Willems, S. P. (2008). Data set-real-world multiechelon supply chains used for inventory optimization. *Manufacturing & Service Operations Management*, *10*(1), 19-23.

Xuan, Q., Du, F., Li, Y., & Wu, T. J. (2011). A framework to model the topological structure of supply networks. *Automation Science and Engineering, IEEE Transactions on*, *8*(2), 442-446.

Yi, C. Q., Meng, S. D., Zhang, D. M., & Li, J. D. (2013). Managing Disruption Risks in Supply Chain Based on Complex Networks. *Journal of Convergence Information Technology*, *8*(5).

Zhao, K., Kumar, A., Harrison, T. P., & Yen, J. (2011). Analyzing the resilience of complex supply network topologies against random and targeted disruptions. *Systems Journal, IEEE*, *5*(1), 28-39.

Zhao, K., Kumar, A., & Yen, J. (2011). Achieving high robustness in supply distribution networks by rewiring. *Engineering Management, IEEE Transactions*, *58*(2), 347-362.

13:30 – 15:30 **Session 1B (Floor 16)** **Chair: Panagiotis Angeloudis**

Theme: Ports (Port connectivity and efficiency)

Terminal Allocation with Considering Bunker Consumption
Lu Zhen

Optimal Path Design for Mesh-like Structure in GRID System
Chenhao Zhou, Zhi Chao Poh, Ek Peng Chew and Loo Hay Lee

An Integrated Approach for Operational Problems in Dry Bulk Terminals
C. Ozgur Unsal and Ceyda Oguz

Optimizing Service System Designs with Congestion by Conic Optimization Formulations
Julio C. Góez and Miguel F. Anjos

Terminal allocation with considering bunker consumption

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Mega-ports in the world are usually multi-terminal port systems rather than single-terminal systems. For example, the port of Singapore has set up eleven terminals phase by phase, including eight container terminals; the port of Hong Kong has nine container terminals situated at Kwai Chung, Stonecutters Island and Tsing Yi; the ports of Rotterdam, Los Angeles, and Shanghai also have nine, nine, and seven container terminals, respectively. In some mega-ports such as Shanghai and Singapore, new terminals are still under construction to meet the increasing demand.

For a single-terminal system, berth allocation decisions may lie in the kernel position because the berth plan has a significant influence on quay crane (QC) schedules, yard storage plans, yard truck routes, etc. Therefore, the berth allocation problem (BAP) becomes one of the most important and popular decision problems for port operators and researchers in the fields of port operations. However, for a multi-terminal system, the terminal allocation lies in a higher decision level than the berth allocation. The former one should be decided before the latter one. Although both the practitioners and the researchers have made a great effort on BAP researches, great attention should also be paid to the terminal allocation problem (TAP) because the TAP acts as the basis for the BAP. The TAP decision also has a great impact on the efficiency of seaside operations and further influences the monetary revenue of a mega-port with multiple terminals.

Terminals and berths belong to two types of resources for a mega-port. Similar to the BAP, the TAP concerns how to maximize the utilization of the resources during the resource allocation processes. However, the TAP also takes account of the transshipment flows among different terminals in a mega-port. For example, if two vessels, between which there exist a large number of transshipped containers, moor at two different terminals, a significant inter-terminal traffic cost will be incurred. It should be noted that most mega-ports in the world are usually container transshipment hubs. The inter-terminal traffic flows become what the port operators of mega-ports concern most, because the inter-terminal traffic related cost has occupied a large percentage of the whole port operation cost. Therefore, it is necessary to investigate the TAP in transshipment hubs with considering the inter-terminal traffic flows.

Both port operators and shipping lines are the important partners in the global maritime transportation system, which has been playing a more and more important role in the international supply chain. The TAP belongs to the decision category of the port operators, but should also consider the concerns and benefits of the shipping lines, for which the bunker consumption is the overwhelmingly dominant part of their operation cost. Shipping lines are trying all possible measures, both technically and managerially, to reduce bunker consumption. It is well known that the bunker consumption is related to the speed of vessels, which further affects their arrival time at the ports. In addition, the vessels' arrival time is also important input data for the TAP. Therefore, the TAP decision has an influence on the bunker consumption cost of shipping lines.

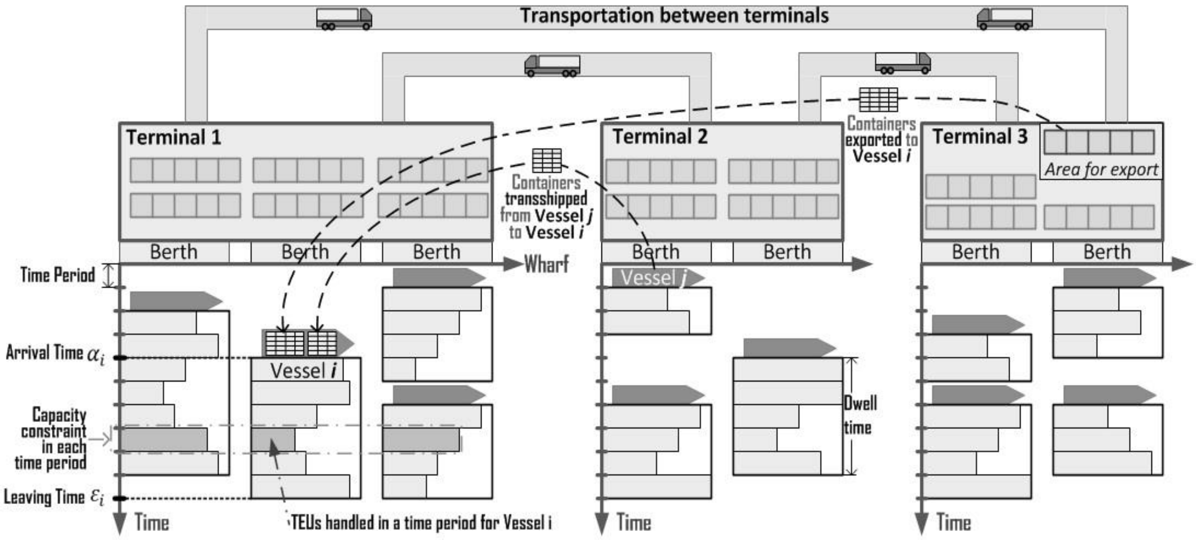

Figure 1: The terminal allocation problem in a multi-terminal port system

According to the above analysis, this paper presents an explorative study on the TAP in transshipment hubs with considering the bunker consumption. The capacity limitation of the resources such as berths and QCs is also taken into account. Different from the widely studied BAP, the TAP in this study further considers the cost related to the inter-terminal traffic flows. Moreover, two types of QC assignment policies within the TAP decision are investigated. Two different TAP models are formulated and analyzed. To solve the proposed mixed-integer programming (MIP) models in large-scale problem instances, both a local branching based solution method and a Particle Swarm Optimization (PSO) based solution method are developed. Extensive numerical experiments are also conducted to validate the effectiveness of the proposed models and the efficiency of the proposed solution methods. The proposed models can save around 14% of the cost when compared with the intuitive FCFS decision rule. Moreover, the numerical experiments also show that the proposed local branching method can obtain near optimal solutions within a much shorter time than the CPLEX solver. The gap from the optimal objective value is only 0.1% on average. In addition, the proposed PSO solution method outperforms the widely used GA based solution method, and can not only solve the proposed model within a reasonable time but can also obtain near-optimal results, with only about 0.7% relative gap from the lower bound.

Optimal Path Design for Mesh-like Structure in GRID System

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6th International Conference on Logistics and Maritime Systems (Sydney, 21-23 June, 2016)

1. Introduction

With the increasing trend of the global container trade, the terminal operators are urgently demanding a yard side solution which can achieve both high land utilization and high handling capacity. As introduced by Zhou et al. (2015), a conceptual design known as the Goods Retrieval and Inventory Distribution (GRID) comprises of two layers: the ground layer for container storage and the sky layer for container transport. The sky layer is a multi-directional overhead mesh-like rail structure with container-handling vehicle, which is known as Transfer Units (TUs, the vehicle). The vehicles travel along the overhead rails and have access to any part of the yard. Due to the use of two layers, this design is capable of achieving both high land density and high throughput. However, the system performance is greatly affected by the vehicle conflicts. The conflicts become serious when the number of vehicles increases until a threshold is reached. Then the throughput starts to decrease. As such, effective conflict prevention methods or rules in the vehicle control logic are imperative in maximizing the efficiency of the GRID system.

Many studies have paid attention to the conflict-free routing problem which can be solved to optimal with a small number of vehicles. Desaulniers et al. (2003) can only solve up to four vehicles within a controllable time while Corréa et al. (2004) are six. The main cause of the limitation is that the travel direction is completely free so the number of the possible routes is tremendously huge.

In the real life, the conflicts happen frequently in the crossroad if vehicles are allowed traveling freely, especially when the traffic is heavy. As the solution, traffic lights and travel direction are set to regulate the vehicle movement to reduce conflicts. Motivated by the above, an innovative solution is proposed for the GRID system: instead of finding the conflict-free vehicle routing and scheduling, the objective is to optimize the path design by restricting the vehicle movement in a single direction along certain paths in the GRID to reduce head-on conflicts.

The remaining sections will be arranged as follows: Section 2 will briefly introduce the methodology used in this study. Section 3 will show the preliminary result and the last section will indicate the roadmap for future works.

2. Methodology

To describe and solve the problem, a mathematic model and related algorithms are proposed. Then a simulation model is built to apply the proposed model and algorithms to recalculate the path design dynamically.

2.1. Mathematic Model and Algorithms

In this study, an integer programming model is proposed to determine the path direction for the GRID structure and then determine the route for each job. The objective is to minimize the total travel distance. The main part of the model is a vehicle routing problem. In addition, a binary decision variable is introduced to control the path direction and a set of constraints is introduced to limit the traffic flow on the adjacent paths which have opposite directions.

As an NP-hard problem, solving the model with commercial software such as CPLEX will be a time consuming work especially in large scale situation, i.e. finding the optimal path design for 10,000 containers. In this case, exact algorithm and heuristic algorithms are proposed and compared.

The insight of the heuristic algorithms will be explained as follows. In the optimal path design problem, path direction is a higher level decision than job routing, i.e. job routing need to be based on the path direction. However, the routing based on current path design may not be the optimal in terms of the objective function which motivates the path design to be updated accordingly. In this case, the hierarchical structure is used in heuristic algorithms which consist of two levels: path design level and routing level. The path design level will roughly determine the path direction based on job information and guarantee that all nodes are accessible by other nodes. Then the routing level will determine the detailed shortest route for each job. After that, the weight of each job will be updated based on its current travel distance and a benchmark. Then the algorithm will return to the path design level and will update the path direction based on the job information with the new weight.

2.2. Simulation Model

Discrete event simulation (DES) has been widely adopted to represent the real operations and evaluate the system performance. In this study, the commercial software AutoMod is used to build the DES model for the GRID system. In Zhou et al. (2015), the vehicle control logic is embedded in the DES model. However, due to the complexity of applying the math model and heuristic algorithms directly in the DES model in the AutoMod, the control system for optimal path design, vehicle dispatching, and vehicle routing is isolated as an independent module, which is written in C++ and C# with Visual Studio and compiled as dynamic-link libraries.

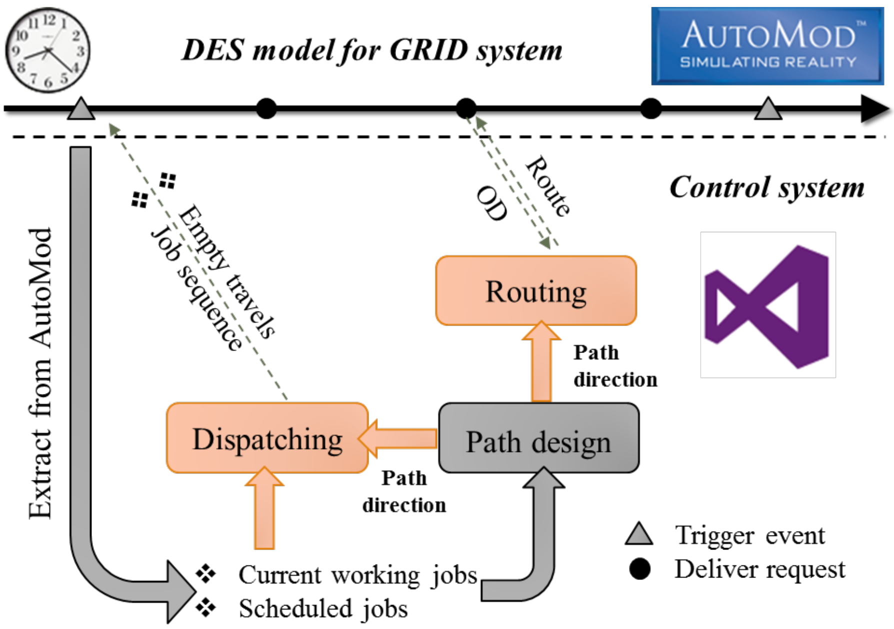

Figure 1: Structure of the DES model and control system

As shown in Figure 1, the DES simulation model is built in AutoMod which is mainly used to simulate the system structure and the vehicle movement. Based on the current path direction, the job handling sequence and the route for each job are calculated by the dispatching control and routing control respectively – the sub-systems of the control system. During the simulation, specific events, such as the beginning of the simulation, the changing of container flow pattern and certain time period, will trigger the control system to update the path design based on current working jobs and future scheduled jobs. Once the path direction is updated, the routing control will provide a new route for the current and future jobs.

3. Preliminary Result

The preliminary experiment is conducted to demonstrate how a simple and rigid path design could affect the system throughput. In the GRID system with 33 columns and 63 rows as shown in Figure 2, the design defines the vertical paths as up, e.g. from 1 to 3, 9 to 13, 19 to 23, 29 to 31, and the rest vertical paths as down, and horizontal paths in the transfer area as either left or right as depicted in the diagram, resulting in an overarching dual-loop shaped traffic policy in the GRID. Besides, vertical paths 4, 8 14, 18, 24 and 28 are defined as “shared” paths where traffic is limited.

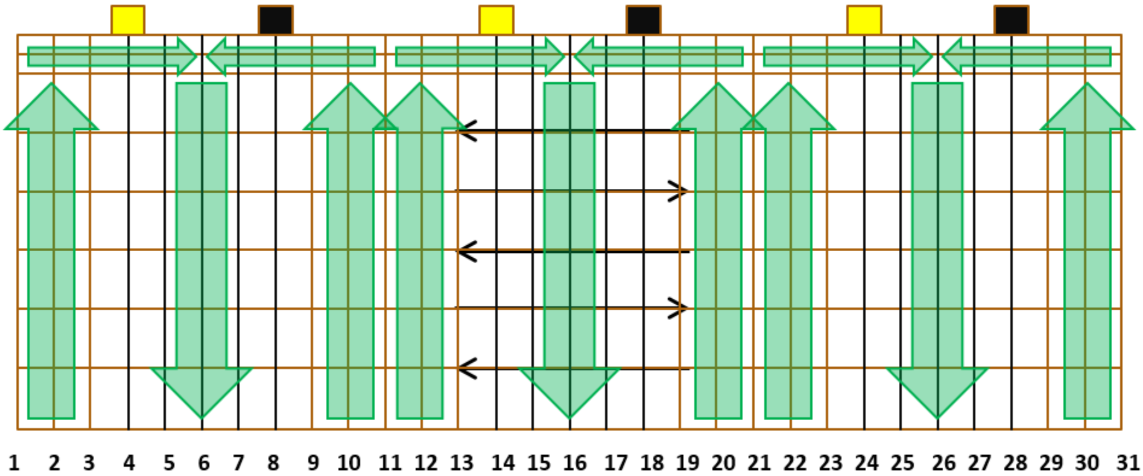

Figure 2: A simple path design for the GRID system with 33 columns and 63 rows

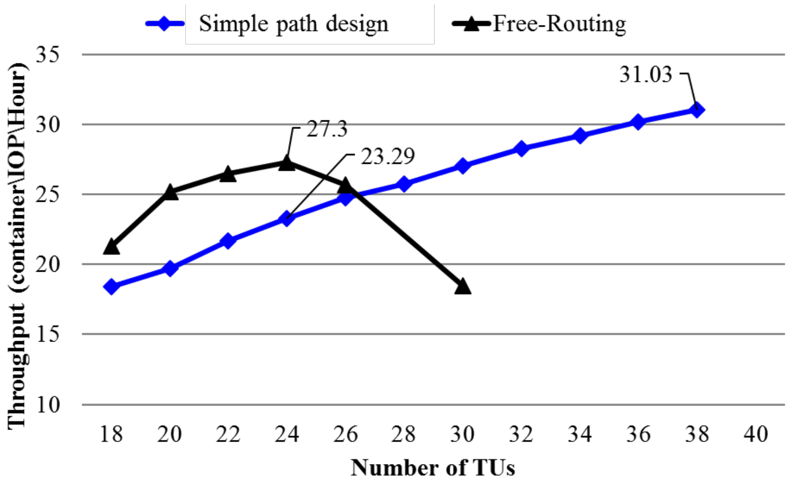

Figure 3: Throughput comparison between free-routing and simple path design

Figure 3 compares the throughput of the free-routing by Zhou et al. (2015) and that of the simple path design. The result shows that the throughput under the traffic rule is not as good as the free-routing when with fewer vehicles. This is due to the fact that the vehicle will not always be assigned the shortest path. Nevertheless, when the number of vehicles increases, simple path design allows vehicles traveling on a designed route without collision enabling the management of many more vehicles.

4. Roadmap

The preliminary result has shown that the design on path direction can be a promising solution to further improve the throughput of the GRID system. In addition, the dispatching control has been proven to be effective to the overall throughput. Besides, the math model and heuristic algorithms have been completed and numerical experiments will be conducted for large scale cases. Eventually, both the math model and the algorithms will be applied in the control system and the whole simulation model can work as designed.

References

Zhou, C., Chew, E. P., Lee, L. H. & Liu, D. (2015). An introduction and performance evaluation of the GRID system for transhipment terminals. *SIMULATION*, Published online before print, December 30, 2015, doi:10.1177/0037549715623845

Corréa, A. I., Langevin, A., & Rousseau, L. M. (2004). *Dispatching and conflict-free routing of automated guided vehicles: A hybrid approach combining constraint programming and mixed integer programming* (pp. 370-379). Springer Berlin Heidelberg.

Desaulniers, G., Langevin, A., Riopel, D., & Villeneuve, B. (2003). Dispatching and conflict-free routing of automated guided vehicles: An exact approach. *International Journal of Flexible Manufacturing Systems*, **15**(4), 309-331.

An Integrated Approach for Operational Problems in Dry Bulk Terminals

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1. Introduction

As volume of maritime transport increases, workload at seaside terminals grows equally and operating seaside terminals efficiently and less costly is becoming more important. Even though bulk loads constitutes more than half of all loads carried by maritime transportation, operational problems of bulk terminals are studied less in the literature compared to those of container terminals. In this study we present an integrated approach for the following operational problems in a dry bulk terminal (DBT):

- Berth Allocation Problem (BAP) to determine berthing time and berthing position for each vessel,
- Yard Allocation Problem (YAP) to determine stocking time and position of stockpiles in stockyard,
- Reclaimer Scheduling Problem (RSP) to determine a schedule for each reclaimer to reclaim stockpiles located at different positions of stockyard.

Barros et al (2011) studied BAP in DBTs under tidal constraints. Umang et al (2013) assumed a hybrid berth layout in studying BAP in DBTs. Hu and Yao (2012) developed a mixed integer programming model for RSP by assuming only one reclaimer in each rail track. Robenek et al (2014) extended the work of Umang et al. (2013) by considering integrated yard allocation and berth allocation operations in a bulk terminal.

Our study is motivated by a DBT exporting coal and the general structure of the terminal can be described as follows: Coal arrives to terminal by rail and stored in the stockyard as stockpiles. After mooring of the vessels to the berths, related stockpiles are reclaimed by reclaimers and transferred via conveyor belt systems to the quay area where vessels are loaded by ship loaders. The departure of the vessels is constrained by high tide periods. It is easy to see that these problems are strongly interrelated. For example berthing position and time for each vessel is determined according to the readiness of the stockpiles. The schedule of the reclaimers will affect the loading of the vessels and hence the time that a vessel can leave the berth. We note that in this study a task is defined as a stockpile of one type of coal to be loaded to a single vessel.

2. Problem Definition

In the integrated problem of DBT operations, there are V vessels with T loading tasks, M berths, H high tide periods, C reclaimers mounted on W rail tracks, and U stocking positions located on each of A pads. The structure of such a terminal for an instance with M=3, C=3, W=2, U=10 and A=3 is given in Figure 1. The problem is to find a solution in which incoming vessels are allocated to berth positions, reclaimers are assigned to vessels, stockpiles are allocated to stockyard and reclaimers are scheduled to reclaim stockpiles while minimizing the total completion times of vessels.

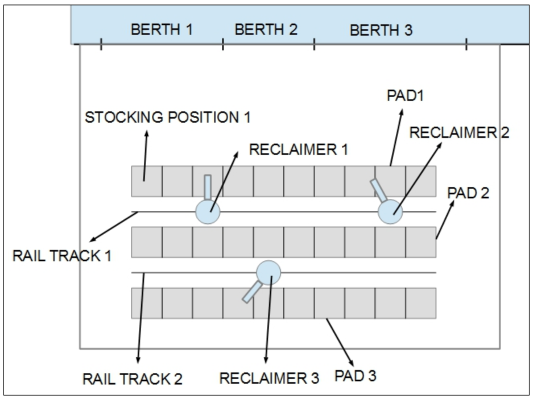

Figure 1: Overview of berth and stockyard

The most important properties and constraints of the problem are listed below.

- We consider a discrete berth layout. Each vessel should moor to one of the berths suitable to its length and vessels assigned to the same berth cannot overlap in time.
- There exist tidal time windows, therefore a vessel can only leave in high tide periods.
- Each vessel can have more than one stockpile to be loaded with and all of these tasks must be performed by a single reclaimer.
- On each rail track, there can be more than one reclaimer machine and these reclaimers cannot pass each other (non-crossing constraint). A reclaimer can only reclaim stockpiles located on pads adjacent to the rail track on which it is mounted. Tasks that are processed by the same reclaimer cannot be reclaimed in overlapping time intervals.
- To complete reclaiming of a stockpile, a reclaimer need to travel back and forth over the rail track between leftmost and rightmost of stockpile 300 times on average (Angelelli et al, 2014). Therefore two reclaimers that are located on the same rail track cannot reclaim two stockpiles simultaneously if these stockpiles are overlapping in time.
- A task (stockpile) may use more than one stock position due to its amount. In this case it is stocked as a rectangular pile that uses multiple adjacent stock positions.
- Stockpiles need to be stacked at the moment that they arrive terminal and stored in the same stocking position until reclaimed by reclaimers. Accordingly stockpiles stored in at least one common stocking position need to be non-overlapping over time.
- To start reclaiming a stockpile, the related vessel needs to be moored to a berth first. Similarly, a vessel needs to wait at berth until all related stockpiles are reclaimed.

3. Solution Methodology

In this study we propose a logic based benders decomposition algorithm (Hooker, 2007) to solve the integrated problem of dry bulk terminals by decomposing it as a master and a sub-problem via mixed integer programming and constraint programming models, respectively. Constraint programming (CP) technique (Baptiste et al, 2001) allows us to cope with hard to solve constraints effectively, however it typically fails to prove optimality. Accordingly to exploit the strength of CP, we model the sub-problem as a feasibility problem rather than an optimization problem. Therefore we solve the master problem first and then solve the feasibility sub-problem iteratively until the sub-problem is feasible.

In our approach, we first decompose the integrated problem into BAP and YAP as the master problem and the sub-problem, respectively. Then we take the most difficult constraint of RSP, that is non-crossing constraint, and add it to the sub-problem, while combining the rest of RSP with the master problem, that is BAP. The idea here is to cope with the most difficult constraint with CP as our previous work show that CP is a proper tool to do that (Unsal and Oguz (2013)).

In this decomposition method it is also very important to add some specific properties of the sub-problem to the master problem as a relaxation (Hooker, 2007). Therefore we add relaxation of YAP to the master problem by limiting the total stocking area used by the stockpiles.

By solving the master problem, we obtain (1) berthing time and position of vessels, (2) departure times of vessels by considering tidal conditions, (3) reclaimer assignments to vessel, and (4) reclaimer schedules, that is the start times of reclaiming stockpiles. Then the information in (1), (2), (3) is sent to the sub-problem and it is checked whether there is a feasible schedule that satisfies the following constraints by solving the CP model:

- Non-crossing constraint of reclaimers that are working on same rail track.
- Stockpiles that are assigned to a specific reclaimer must be located on pads adjacent to the rail track that this reclaimer mounted on.
- Stockpiles stored in at least one common pad need to be non-overlapping over time.

If sub-problem finds a feasible solution, then algorithm terminates. In case of an infeasible sub-problem, we derive cuts for infeasibilities caused by non-crossing constraint and by non-overlapping of stockpiles and add them to the master problem.

In logic based benders decomposition there are different types of cuts. If cut is proved to be does not eliminate optimal solution, then it is called a valid cut. The smallest valid cut is called "no-good" cut that forbids the current values of all problem variables. When there is no such proof, the cut turns into a trial cut. Therefore if we use trial cuts we lose algorithms ability to prove optimality. In this study the cuts are trial cut; that is the method turns into a heuristic one if at least one cut is added.

4. Results and conclusions

We designed a computational experiment to measure the performance of the proposed method. Accordingly we generated three scenarios by considering a terminal consists of 3 pads, with 10 stocking positions in each, and 2 rail tracks between these pads. During the planning horizon there are 10 high tide periods. These scenarios consist of (i) 4 berths – 3 reclaimers, (ii) 3 berths – 4 reclaimers and (iii) 4 berths – 4 reclaimers. For each scenario we assume that there are 10 arriving vessels and the number of total stockpiles is taken as 10, 15 and 20. For each combination, we generated 5 different problem instances. As a result we have 3x3x5=45 instances. All components of the method were implemented by ILOG Concert, ILOG Cplex 12.5 and ILOG CP Optimizer, and solved by a computer that has 2.7 Ghz processor and 8 GB memory with a time limit of two hours.

Table 1: Results of computational experiments

	Ins.	# of tasks	Lower Bound	Final value	Time (mins.)	% GAP		Ins.	# of tasks	Lower Bound	Final value	Time (mins.)	% GAP		Ins.	# of tasks	Lower Bound	Final value	Time (mins.)	% GAP
3 Berths – 4 Reclaimers	1	10	683	683	0.3	0	4 Berths – 3 Reclaimers	16	10	695	695	0.2	0	4 Berths – 4 Reclaimers	31	10	621	621	1	0
	2	10	641	641	0.1	0		17	10	715	715	0.1	0		32	10	588	588	0.3	0
	3	10	701	701	0.1	0		18	10	740	740	0.1	0		33	10	666	666	0.8	0
	4	10	744	744	0.2	0		19	10	799	799	0.2	0		34	10	671	671	0.2	0
	5	10	800	800	0.3	0		20	10	736	736	0.1	0		35	10	705	705	0.3	0
	6	15	910	910	1	0		21	15	789	789	2	0		36	15	778	778	62	0
	7	15	895	895	12	0		22	15	844	844	3	0		37	15	880	880	17	0
	8	15	902	902	4	0		23	15	910	910	1	0		38	15	841	841	30	0
	9	15	880	880	17	0		24	15	900	900	0.6	0		39	15	820	820	19	0
	10	15	699	699	3	0		25	15	871	871	1	0		40	15	888	888	44	0
	11	20	1094	1094	44	0		26	20	1014	1017	30	0.30		41	20	951	951	35	0
	12	20	1001	1002	37	0.10		27	20	1050	1050	9	0		42	20	910	911	69	0.10
	13	20	1116	1116	29	0		28	20	1181	1181	25	0		43	20	945	945	12	0
	14	20	1069	1069	55	0		29	20	998	998	48	0		44	20	914	914	75	0
	15	20	1199	1199	7	0		30	20	1100	1102	36	0.18		45	20	1003	1007	110	0.40

Results are presented in Table 1, in which the lower bound indicates the optimal solution of the master problem in the first iteration. In the results we first note that we are able to solve all of the instances within the time limit. As expected, solution times increase with the number of tasks.

It can be observed that in 40 out of 45 instances, the final value equals to the lower bound value. The success of the method is due to the quality of the lower bounds generated. The main reason of this can be explained as follows. In the integrated problem of DBTs, the duration of a vessel's stay in the berth is mainly determined by the tidal conditions and the reclaimer schedules. Therefore having the tidal conditions constraints, the vessel-to-reclaimer assignments, a strong relaxation of YAP and non-overlapping constraint for reclaimers in the master problem allows us to estimate these durations for vessels successfully. As a consequence, the rest of the problem turns into finding a feasible allocation of tasks to the stockyard with respect to the constraints of the sub-problem.

Moreover we observed that if we send start times of reclaiming stockpiles to the sub-problem, we frequently face infeasible solutions because of non-crossing constraint. As we mentioned in Section 3, part (4) of the solution of master problem is not sent to the sub-problem and by this way we allow sub-problem not to consider this constraint by switching reclaiming order of tasks that are assigned to the same vessel without increasing the duration of a vessel's stay in the berth.

References

V H Barros, T S Costa, A C M Oliveira and L A N Lorena (2011) Model and Heuristic for Berth Allocation in Tidal Bulk Ports with Stock Level Constraints. *Computers & Industrial Engineering*, **60**, 606-613.

N Umang, M Bierlaire and I Vacca (2013) Exact and Heuristic Methods to Solve the Berth Allocation Problem in Bulk Ports. *Transportation Research Part E*, **54**, 14-31.

D Hu and Z Yao (2012) Stacker-reclaimer Scheduling in a Dry Bulk Terminal. *International Journal of Computer Integrated Manufacturing*, **25**, 1047-1058.

T Robenek, N Umang, M Bierlaire and S Ropke (2014) A Branch-and-Price Algorithm to Solve the Integrated Berth Allocation and Yard Assignment Problem in Bulk Ports. *European Journal of Operational Research*, **235**, 399-411.

E Angelelli, T Kalinowski, R Kapoor and M W P Savelsbergh (2014) A Reclaimer Scheduling Problem Arising in Coal Stockyard Management. arXiv:1402.4178.

J N Hooker (2007) Planning and Scheduling by Logic-Based Benders Decomposition. *Operations Research*, **55**, 588-602.

O Unsal and C Oguz (2013) Constraint Programming Approach To Quay Crane Scheduling Problem. *Transportation Research Part E: Logistics and Transportation Review*, **59**, 108-122.

P Baptiste, C Le Pape and W Nuijten (2001) Constraint-Based Scheduling. Boston: Kluwer Academic Publishers.

Optimizing service system designs with congestion by conic optimization formulations

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1 Introduction

In this paper we consider the service system design problem with congestion. This problem is encountered at the design of cost effective distribution strategies. The goal is to locate warehouses closer to customers and dispatch shipments from these warehouses rather than directly from the plants. To formulate the problem, consider a set of costumer locations indexed by i, the possible locations for facilities indexed by j, and a set of capacities levels for the facilities indexed by k. Denote by $\lambda_i \geq 0$ the mean demand rate for consumer i, and by $\mu_{jk} \geq 0$ the mean service rate of server of type k at facility j. The problem is to decide the location of the facilities, allocate enough capacity μ_{jk}, and assign costumers to the facilities such that the demand of each costumer is satisfied. The goal is to minimize the sum of the cost p_{jk} of opening and allocating enough capacity in the facilities, the access cost c_{ij} of the costumer i to the facility j, and the queuing delay cost per time unit d. For modeling the queuing delay, we assume that each server facility behaves as an independent $M/M/1$ queue. Using this assumption we obtain the following mixed integer non-linear optimization model [1]:

$$\min \sum_{i=1}^{\ell}\sum_{j=1}^{m} c_{ij}x_{ij} + d\sum_{j=1}^{m} \frac{\sum_{i=1}^{\ell}\lambda_i x_{ij}}{\sum_{k=1}^{n}\mu_{jk}y_{jk} - \sum_{i=1}^{\ell}\lambda_i x_{ij}} + \sum_{j=1}^{m}\sum_{k=1}^{n} p_{jk}y_{jk} \tag{1}$$

$$\text{s.t.} \sum_{k=1}^{n}\mu_{jk}y_{jk} - \sum_{i=1}^{\ell}\lambda_i x_{ij} \geq 0 \quad j = 1,\ldots,m \tag{2}$$

$$\sum_{k=1}^{n} y_{jk} \leq 1 \quad j = 1,\ldots,m \tag{3}$$

$$\sum_{j=1}^{m} x_{ij} = 1 \quad i = 1,\ldots,\ell \tag{4}$$

$$x_{ij}, y_{jk} \in \{0,1\} \quad i = 1,\ldots,\ell; \quad j = 1,\ldots,m; \quad k = 1,\ldots,n \tag{5}$$

Note that if $d < 0$, then the model will reward the queuing delay in the system. In general this goes against the purpose of service system design. Furthermore, if $d < 0$ then the objective function (1) will go to infinity, preferring unstable solutions. For this reason, we may assume throughout this paper that $d \geq 0$.

Different solution approaches have been proposed in the literature for this problem. Amiri [1] proposed a heuristic based in Lagrangean relaxation. Also, Elhedhli [7,8] designed an exact algorithm based on outer linear approximations, and proposed a equivalent mixed integer linear optimization (MILO) formulation. This problem has been also used as a testing problem for several techniques used to solve mixed integer nonlinear problems. Examples of these techniques are disjunctive cuts [14], perspective reformulations [9], outer-inner approximation [11], and strong-branching inequalities [15].

Our contribution in this paper is the formulation of (1) – (5) as a mixed integer second order cone optimization (MISOCO) problem. This approach aims to profit from the methodological developments that have been recently proposed [2–4, 6, 16, 17]. Also, it aims to take advantage from the power of off-the-shelf solvers that provide capabilities to solve MISOCO problem [10, 13, 18]. We compare numerically our formulations against the techniques and MILO equivalent reformulation proposed in [7, 8]. This experimentation shows that using a MISOCO formulation allows to obtain a comparable performance with the existing exact methods.

2 MISOCO formulations approach

There are several models that are proposed in this work. Our strategy focus on dealing with the objective function of Problem (1) – (5), which can lead to the indeterminate form $\frac{0}{0}$ in the second term when a server in not used. To avoid this situation we propose two ways of linearizing the objective. First, we need to reformulate the term

$$d\sum_{j=1}^{m}\frac{\sum_{i=1}^{\ell}\lambda_i x_{ij}}{\sum_{k=1}^{n}\mu_{jk}y_{jk}-\sum_{i=1}^{\ell}\lambda_i x_{ij}}.$$

Recall that $\lambda_i \geq 0$ and $\mu_{ij} \geq 0$, and assume for this step that $\sum_{k=1}^{n}\mu_{jk}y_{jk}-\sum_{i=1}^{\ell}\lambda_i x_{ij} > 0$. From these conditions we obtain that

$$\frac{\sum_{i=1}^{\ell}\lambda_i x_{ij}}{\sum_{k=1}^{n}\mu_{jk}y_{jk}-\sum_{i=1}^{\ell}\lambda_i x_{ij}} \geq 0,\ j=1,\ldots,m. \tag{6}$$

Now, consider the following inequalities

$$\frac{\sum_{i=1}^{\ell}\lambda_i x_{ij}}{\sum_{k=1}^{n}\mu_{jk}y_{jk}-\sum_{i=1}^{\ell}\lambda_i x_{ij}} \leq s_j, \quad s_j \geq 0, \quad j=1,\ldots,m. \tag{7}$$

Adding these inequalities to (2) – (5), one obtain the following linear objective function:

$$\min \sum_{i=1}^{\ell}\sum_{j=1}^{m} c_{ij}x_{ij} + d\sum_{j=1}^{m}\sum_{j=1}^{m} s_j + \sum_{j=1}^{m}\sum_{k=1}^{n} p_{jk}y_{jk} \tag{8}$$

An alternative to (7) may be obtain by using the traffic intensity of a $M/M/1$ as follows:

$$s_j \geq \frac{\rho}{1-\rho}, \quad \rho_j \geq \frac{\sum_{i=1}^{\ell}\lambda_i x_{ij}}{\sum_{k=1}^{n}\mu_{jk}y_{jk}}, \quad s_j \geq 0, \quad j=1,\ldots,m. \tag{9}$$

Equations (7) and (9) may be used as alternatives, combined with the binary constraint over x_{ij} and y_{jk}, to model (2) – (5) as a MISOCO in different ways. Our goal in this work is to numerically explore which is the best model to solve realistic versions of this problem.

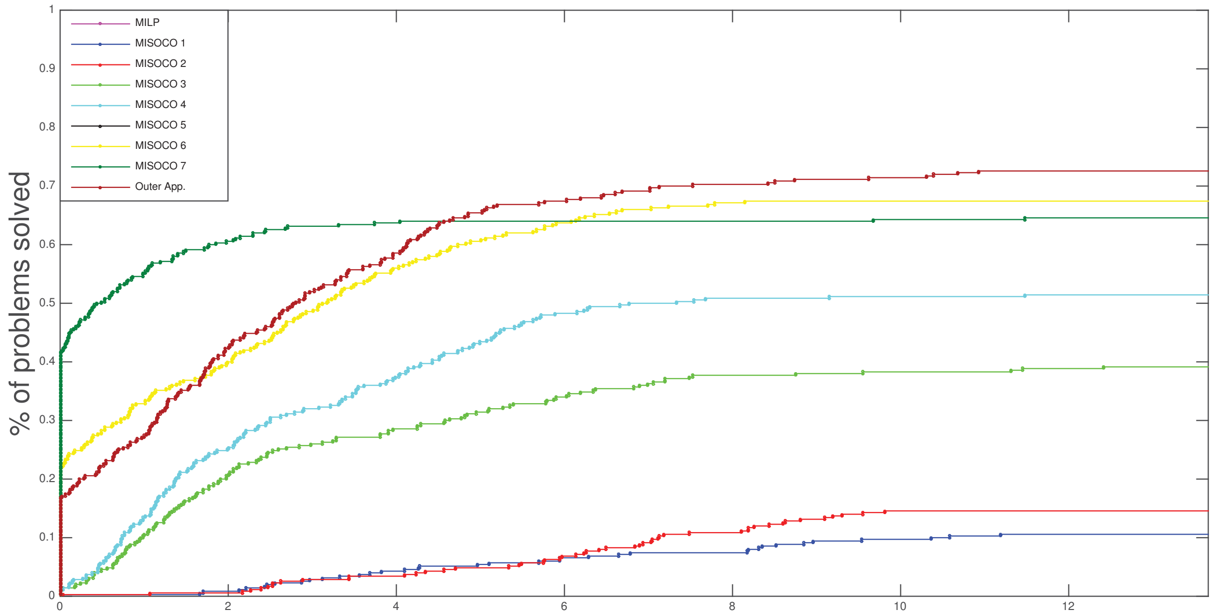

Figure 1: Performance profile based in cpu time in seconds

3 Computational results and conclusions

For our numerical tests we use the sets from Holmberg et al. [12]. We modified this instances using the procedure described in [8]. In this experiments we use Cplex 12.6.3 to solve the conic problems, and put a limit of 5 cpu hours for the solution time. As a bench mark we use the milp formulation and the outer approximation proposed in [7, 8]. We use cpu time to measure the performance of the formulations. Figure 1 shows the performance profile [5] for seven possible MISOCO formulations. In that figure the best performance is determined by the line that is to the most left and top in the plot. There one can observe that none of the formulations was capable of solving 100% of the problems within the time limit, which is indicated in the vertical axis. The horizontal axis is a function of the solution time, and moving to the right relaxes the tolerance for how far from the best time for each problem we accept a formulation. From these results we have that with probability of about 0.42 MISOCO 7 is the best formulation. Now, if one chooses to be within a factor of 4 or more of the best solver then MISOCO 6 and 7, and the outer linear approximation from [8] would suffice.

References

[1] A. Amiri. Solution procedures for the service system design problem. *Computers & Operations Research*, 24(1):49 – 60, 1997.

[2] A. Atamtürk and V. Narayanan. Conic mixed-integer rounding cuts. *Mathematical Programming*, 122(1):1–20, 2010.

[3] P. Belotti, J. C. Góez, I. Pólik, T. K. Ralphs, and T. Terlaky. A conic representation of the convex hull of disjunctive sets and conic cuts for integer second order cone optimization. In M. Al-Baali,

L. Grandinetti, and A. Purnama, editors, *Recent Developments in Numerical Analysis and Optimization*, Springer Proceedings in Mathematics and Statistics. Springer, 2015. in press.

[4] P. Belotti, J. C. Góez, I. Pólik, T. K. Ralphs, and T. Terlaky. Disjunctive conic cuts for mixed integer second order cone optimization. Technical Report G-2015-98, GERAD, September 2015.

[5] D.E. Dolan and J.J. Moré. Benchmarking optimization software with performance profiles. *Mathematical Programming*, 91(2):201–213, 2002.

[6] S. Drewes. *Mixed Integer Second Order Cone Programming*. PhD thesis, Technische Universität Darmstadt, Germany, 2009.

[7] S. Elhedhli. Exact solution of a class of nonlinear knapsack problems. *Operations Research Letters*, 33(6):615 – 624, 2005.

[8] S. Elhedhli. Service system design with immobile servers, stochastic demand, and congestion. *Manufacturing & Service Operations Management*, 8(1):92–97, 2006.

[9] O. Günlük and J. Linderoth. Perspective reformulation and applications. In Jon Lee and Sven Leyffer, editors, *Mixed Integer Nonlinear Programming*, volume 154 of *The IMA Volumes in Mathematics and its Applications*, pages 61–89. Springer New York, 2012.

[10] GUROBI. *gurobi*, 2014.

[11] H. Hijazi, P. Bonami, and A. Ouorou. An outer-inner approximation for separable mixed-integer nonlinear programs. *INFORMS Journal on Computing*, 26(1):31–44, 2014.

[12] K. Holmberg, M. Ronnqvist, and D. Yuan. An exact algorithm for the capacitated facility location problem with single sourcing. *European Journal of Operational Research*, 113(3):544–559, March 1999.

[13] IBM. *IBM ILOG CPLEX Optimization Studio V12.4*, 2013.

[14] M. Kılınç, J. Linderoth, and J. Luedtke. Effective separation of disjunctive cuts for convex mixed integer nonlinear programs. *Optimization Online*, 2010.

[15] M. Kılınç, J. Linderoth, J. Luedtke, and A. Miller. Strong-branching inequalities for convex mixed integer nonlinear programs. *Computational Optimization and Applications*, 59(3):639–665, 2014.

[16] F. Kılınç-Karzan and S. Yıldız. Two-term disjunctions on the second-order cone. In J. Lee and J. Vygen, editors, *Integer Programming and Combinatorial Optimization*, volume 8494 of *Lecture Notes in Computer Science*, pages 345–356. Springer International Publishing, 2014.

[17] S. Modaresi, M. R. Kılınç, and J. P. Vielma. Split cuts and extended formulations for mixed integer conic quadratic programming. *Operations Research Letters*, 43(1):10 – 15, 2015.

[18] MOSEK. *The MOSEK optimization tools manual, Version 7.0*, 2013.

16:00 – 18:00	Session 2A (Floor 17)	Chair: Shuaian Wang
	Theme: Ports (Berth and crane scheduling problems)	

Robust Berth Allocation for Minimizing Conflicts with Planned Schedule
Fan Wang, Jinjia Huang and Zhou Xu

The Quay Crane Scheduling Problem with Steel Rope Renewals
Feifeng Zheng, Zizhen Zhang, Yanzhi Li and Songshan Guo

Measurement of Port Operational Performance using Data Envelopment Analysis
Sirawadee Arunyanart

An Integrated Scheduling of Berth and Quay Cranes with Maintenance Activities
Feifeng Zheng, Ying Li and Ming Liu

Robust berth allocation for minimizing conflicts with planned schedule

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1. Introduction

Container terminals play an important role in the maritime transport chain. In this study, we consider a berth allocation problem in container terminals in which the assignment of vessels to berths is subject to uncertainty. Berth allocation focuses on finding optimal assignments of vessels to berths given planned schedule (i.e., estimated vessel arrival and departure time), where certain targets are met. Specifically, each vessel requests berth service with an estimated arrival and departure time in advance. Then an initial berth assignment plan based on the requested time is obtained, in which each vessel is assigned to exactly one berth while some objectives are optimized. During peak hours, due to the scarceness of berth resources, some vessels have to be delayed or positioned in other places for service (i.e., un-berthed vessel). Meanwhile, actual vessel arrival times to a container terminal in each time period (say, every day) are subject to considerate uncertainty (e.g., adverse weather), and result in disturbances with respect to the requested times. We concentrate on vessel arrival time delays in discrete berth allocation setting. Conflict occurs when different vessels were scheduled to occupy the same berth in different time periods but their actual requested times lie in the same time instance or overlapped time intervals.

In this study, we aim to propose a mathematical framework tackling conflicts in discrete berth allocation with a realistic recovery decisions. We first present a minimum cost flow formulation which explicitly models the relation between a vessel pair. And we propose a new conflict measure aiming to quantify the total number of conflicts. Then we develop a robust optimization model that presents the penalty cost for un-berthed vessels and the recovery cost for conflicts in the objective function. We prove the equivalent linear form for the robust counterpart without increasing the complexity of original model. The numerical studies demonstrate the effectiveness of our robust approach.

2. Methodology

For two vessels assigned consecutively to the same berth, we define it as a vessel pair. There are some "strict" constraints that should be satisfied during the assignment process as follows: (1) Each vessel must be assigned to one and only one berth. (2) Two vessels with overlapping berth service time are not allowed to be served in the same berth.

The deterministic berth allocation models provide assignment based on a planned schedule, and we solve these models by an elaborately designed network which has the form (Ahuja et al 1993):

$$\min \sum_{(i,j)\in A} c_{i,j} x_{i,j} \quad (1)$$

Subject to

$$\sum_{\{j:(i,j)\in A\}} x_{i,j} - \sum_{\{j:(j,i)\in A\}} x_{j,i} = b(i), \forall\, i \in N \quad (2)$$

$$l_{i,j} \le x_{i,j} \le u_{i,j}\ \forall (i,j) \in A_v \quad (3)$$

where $\sum_{i\in N} b(i) = 0$

Then we propose a new conflict measure which reflects how perturbations affect the berth allocation and allows us to quantify the number of conflicts.

To model uncertainty in vessel arrival times, let a_i belong to a symmetric interval $[\bar{a}_i - \hat{a}_i, \bar{a}_i + \hat{a}_i]$ centered at the estimated value $\bar{a}_i$. We restrict the total amount of arrival time disturbances to be bounded. We adopt the approach proposed by Bertsimas and Sim (2003, 2004) to construct the uncertainty set as follows:

$$\Theta = \{\delta \in \mathbb{U}^{|\mathcal{E}|} : ||\delta||_1 \leq \Gamma\} \tag{4}$$

where

$$\mathbb{U} = \{\delta_e | \delta_e = \hat{a}_e w_e, -1 \leq w_e \leq 1\} \tag{5}$$

Parameter Γ specifies the maximum amount of disturbances that vessel arrival time may deviate from the estimated one. When $\Gamma = 0$, we obtain the nominal solution based on the planned schedule. When $\Gamma \geq 0$, we try to protect against all potential realizations under the bounded total disturbances.

In the following we present the robust berth allocation model based on the conflict measure $f(y, \delta)$, where the robust counterpart of the objective function calls for the minimization of recovery cost for potential conflicts.

$$Z^* = \min c(y) + \max_{\delta \in \mathbb{U}^{|\mathcal{E}|}} f(y, \delta) \tag{6}$$

Subject to

$$y \in Y \tag{7}$$

where $y \in Y$ represents the feasible solution.

It is worth mentioning that we have proved the robust model (6)~(7) can be transformed to an equivalent linear form under predefined recovery rules. Therefore, the robust model can be solved in polynomial time.

3. Numerical results and conclusions

The numerical experiment is based on four randomly generated data instances which consists of 70 vessels with 5 berths. More specifically, the estimated arrival time of vessel *i* is randomly generated in the interval $[a_{i-1}, a_{i-1}+40]$, and the berth service time for each vessel is randomly generated between [60, 100]. The delay of vessel arrival time is randomly generated in the interval [0, 60]. The deviations of all vessels considered in the robust model are set to 45 minutes. Our models were implemented in JAVA and tested on a PC Core I7, 2.40GHz, 2.39GHz with a 8GB RAM. We used the callable library CPLEX 12.0 to solve the models.

In Table 1, the nominal solutions are obtained by the minimum cost flow model based on the planned schedule. We show the number of un-berthed vessels (Un-berthed), the actual conflict number (AC), and the associated computing time (CPU). For the robust solutions, we also show the potential conflict number (PC), the value of Γ, the percentage actual conflict reduction (A-reduction) with respect to the nominal solution. Note that the value of Γ is expressed in minutes, while the computing times are all expressed in microseconds.

Table 1: Results for the randomly generated instances of berth allocation problems

Instance	Nominal solution			Robust solution					
	Un-berthed	AC	CPU	Un-berthed	PC	AC	Γ	A-reduction	CPU
1	9	31	318	9	10	29	100	6%	3658
2	10	30	348	10	12	28	100	7%	3670
3	12	30	315	12	7	27	100	10%	3248
4	4	41	348	4	6	26	100	37%	3744

1	9	31	318	9	19	28	300	10%	3516
2	10	30	348	10	22	25	300	17%	3666
3	12	30	315	12	15	26	300	13%	3331
4	4	41	348	4	14	26	300	37%	3683
1	9	31	318	9	25	28	500	10%	3690
2	10	30	348	10	29	24	500	20%	3350
3	12	30	315	12	22	27	500	10%	3343
4	4	41	348	4	20	26	500	37%	3664
1	9	31	318	9	27	20	700	35%	3758
2	10	30	348	10	36	23	700	23%	3674
3	12	30	315	12	27	22	700	27%	3655
4	4	41	348	4	25	22	700	46%	3296

The preliminary results show that, our robust model always obtains solutions with a notably smaller conflict number than the corresponding nominal ones while preserving the same number of un-berthed vessels. It also shows that the larger value of Γ obtains solutions with less actual conflicts.

In summary, we have proposed a robust framework to tackle the berth allocation problem facing uncertainty. This framework introduces a new conflict measure, and develops a minimum cost flow model to explicitly handle the relationship between two events. Further, we will test the model performance on the real-life data from container terminals. Also more realistic constraints in berth allocation will be considered in our future work.

References

Ahuja, R.K., Magnanti, T.L. & Orlin, J.B. (1993), "Network Flows: Theory, Algorithms, and Applications", *Prentice Hall*.

Bertsimas, D. & Sim, M. (2003), "Robust discrete optimization and network flows.", *Mathematical Programming,* Vol. 98 No. 1-3, pp. 49-71.

Bertsimas, D. & Sim, M. (2004), "The Price of Robustness", *Operations Research,* Vol. 52 No. 1, pp. 35-53.

The Quay Crane Scheduling Problem with Rope Renewals

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Abstract: In a container terminal, steel rope renewals commonly occur in the daily practices of quay crane scheduling, however, these maintenance activities have been ignored in the literature. In this work, we investigate the quay crane scheduling problem with consideration of rope renewals (QCSP-RR for short), an operational level problem at container ports. We formulate a mathematical model to incorporate rope renewal activities into the quay crane scheduling problem. We then propose an efficient heuristic method for solving the QCSP-RR in a reasonable time. Numerical experiments are conducted to demonstrate the competitive performance of our solution method.

1. Introduction

In a container terminal, Quay Crane (QC for short) is one kind of critical wharf apron resource in service, and one of its regular maintenance activities is to replace consumptive material such as steel rope based on its accumulated workload. As the triumvirate of industry experts said, regular QC maintenance is so important that there is no substitute for this activity. There is an accident that a crane suddenly collapsed at a port in Asia due to steel rope failure. The reason of deferring the rope replacement is actually because of operational pressure. If the rope had been replaced earlier and timely, such tragedy as well as lots of corresponding economic and time costs could be avoid. We shall recognize the importance of strictly fulfilling QC maintenance schedule, especially executing steel rope renewal activities (see Figure 1).

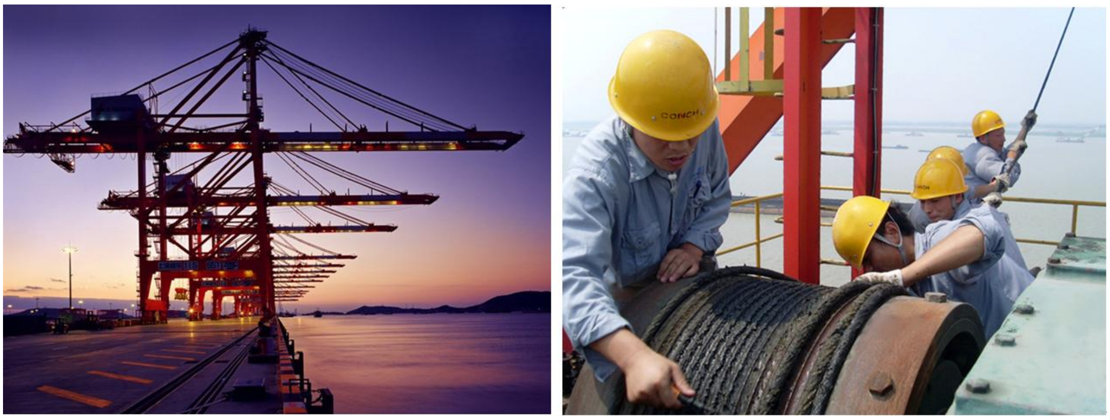


Figure 1. A steel rope renewal activity in the container terminal

Generally speaking, a rope renewal activity for any QC must be carried out after it has completed about 80,000 TEUs with the current steel rope. This is determined by the life of ropes. For example, the average life of steel ropes produced by Japanese companies is 2500 hours. In recent years, there is a trend of increasing the size as well as the load volume of a vessel. With the launch of the MSC OSCAR, which is of length 395.4 metres and width 59 metres, Mediterranean Shipping Company (MSC) sets the newest record with 19224 TEU capacity. For a larger vessel, it consumes more times on average to unload (or load) a container off (or onto) the vessel since the container spreader of a QC moves farther. This implies that the replacement of steel rope for the QC may be required after it serves a less number of TEUs.

We observe that for a large vessel, each QC may be assigned a group of tasks with over a thousand TEUs. Then an activity of steel rope renewal for a QC may sometimes happen during the service. Of course, such activity occurs at most once for each QC according to the service capacity of a new steel rope mentioned above. As a kind of key equipment, the quay cranes generally run 24 hours a day while operators work in three shifts. Thus, in the QC scheduling process, a terminal manager needs to take into consideration such maintenance activity for the sake of QCs' operational safety. Furthermore, compared with the total service time of a vessel usually within one or two days, each rope renewal activity consumes nearly two hours or even longer, and thus the unavailable time interval during the activity shall not be ignored in QC scheduling. In the tactical level problem, i.e., the quay crane allocation, the details of QC scheduling are not considered by the terminal manager. However, in the operational level problem, i.e., the quay crane scheduling, the rope renewal activities must be explicitly considered.

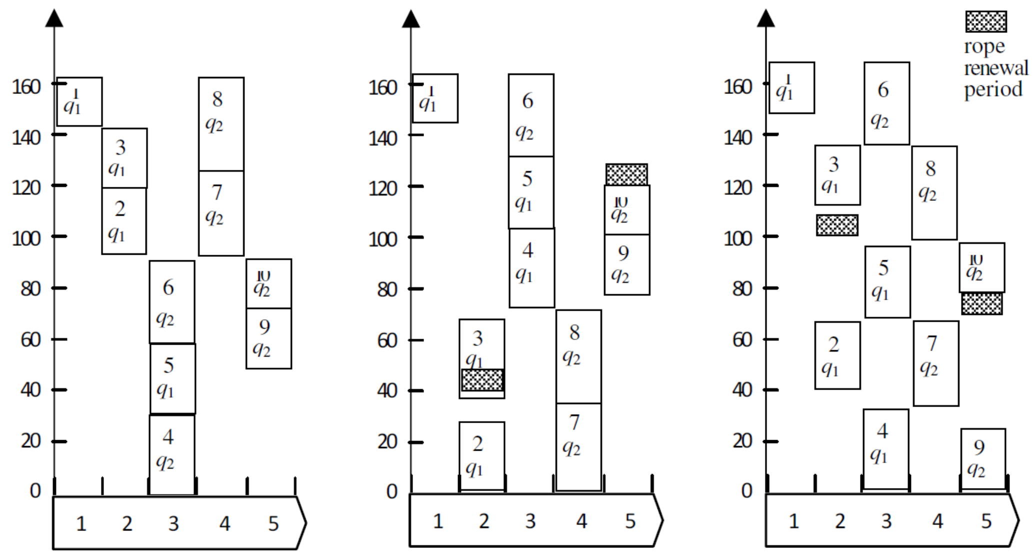
2. Problem Definition

In the QCSP-RR problem, it is given a set of tasks on a container vessel such that each task consists of a group of containers in the same bay and several tasks may share a bay (Bierwirth and Meisel, 2009). Since containers are stored in stacks, those containers in lower tiers must be loaded (or unloaded) before (or after) the other containers piled in high tiers. In this regard, precedence relations should occur between any two tasks in the same bay. For notational convenience, we assume that the involved containers in all tasks are of uniform loading (or unloading) operations. For the case with both loading and unloading container tasks, the precedence relations can be similarly described such that tasks with unloading containers must be handled prior to those with loading containers in the same bay.

A small number of identical QCs which were previously allocated to the vessel perform the processing of the tasks. Each task is assigned and handled by exactly one of the QCs. Preemption is not allowed during the processing of a task but interruption caused by a steel rope renewal activity on the corresponding QC is permitted. The processing of the interrupted task is resumed on the same QC immediately after the renewal. We index the QCs (1, 2, …, Q) sequentially according to their increasing positions along the quay where Q is the number of QCs allocated to the vessel. Each QC is associated with a ready time and an initial position along the quay, which are determined by the processing of its preceding task. On the completion of a task, the QC moves to the bay location of its next task, if any, following the non-crossing constraint. We assume that any QC takes one unit of time to move a unit length of distance. Moreover, for safety reasons, any two adjacent QCs must keep a safety margin in between at all time.

In this paper, we focus on the scenario that some of the QCs may require steel rope renewals during the service of the vessel. The renewals result in unavailable time segments for the corresponding QCs and potentially affect the final QC schedules. It is assumed that the start and end time of a renewal activity is predetermined via some terminal operation management software according to the accumulated workload of the relevant QC together with its current assignment of tasks. The objective of the considered problem is to minimize the turnaround time of the vessel, i.e., the completion time of the last satisfied task.

Below is an example to reveal that the involvement of QC steel rope renewals induces an obvious change of the task assignment and the processing schedule. We are given two QCs, i.e., q_1 and q_2, to handle ten tasks with processing times (20, 26, 23, 30, 28, 33, 34, 37, 23, 19). The ten tasks are distributed among five bays and are all available at time 0. The precedence relations are denoted by their bay indices id_{bay} = (1, 2, 2, 3, 3, 3, 4, 4, 5, 5). A task with smaller index is of higher prior in the same bay. For example, according to id_{bay}, the second and third tasks are both in the second bay and then the former task must be completed before the start of the latter task. We assume that the safety distance between q_1 and q_2 is the length of one bay or one unit of length. Consider the following three cases. In Case 1 there is no steel rope renewal; in Case 2 the two QCs change ropes in time intervals (40, 48) and (120, 128) respectively; and in Case 3 the two time intervals are (100, 108) and (70, 78) for q_1 and q_2 respectively. Figure 2 shows an illustrative process of task processing and steel rope renewal in the above three cases. The horizontal axis represents the five bays (1, 2, 3, 4, 5), and the vertical axis represents the time. Each rectangle represents a task, and the arabic number within the rectangle is the task index. The corresponding QC processing the task is labeled beneath the task index. By the figure, we have that the two QCs respectively process jobs in sequences (5, 6, 2, 3, 1) and (4, 9, 10, 7, 8) in Case 1; (2, 3, 4, 5, 1) and (7, 8, 9, 10, 6) in Case 2, and (4, 2, 5, 3, 1) and (9, 7, 10, 8, 6) in Case 3. We intuitively observe that the rope renewal activities indeed influence the optimal processing schedule and the optimal objective value as well.



a) the case with c_{max}=163 b) the case with c_{max}=164 c) the case with c_{max}=169

Fig. 2: An illustration of task processing and steel rope renewal.

It has been mentioned that the classic QCSP problem is NP-hard (Sammarra et al., 2007). By setting no time consuming for rope renewal activities, the QCSP-RR problem reduces to the QCSP problem and thus its NP-hardness is straightforward.

The remaining work on the QCSP-RR is still in progress. We will present a mathematical model to formulate the QCSP-RR. An efficient heuristic method will be proposed for solving the QCSP-RR. Extensive experiments will be conducted to demonstrate the effectiveness of our method. We will also analyze the effect of steel rope renewals on QC schedules.

References

Bierwirth C, Meisel F (2009) A fast heuristic for quay crane scheduling with interference constraints. *Journal of Scheduling* **12**(4): 345-360.

Bierwirth C, Meisel F (2010) A survey of berth allocation and quay crane scheduling problems in container terminals. *European Journal of Operational Research* **202**(3): 615-627.

Kim KH, Park Y-M (2004) A crane scheduling method for port container terminals. *European Journal of Operational Research* **156**(3): 752-768.

Lee CY, Liu M, Chu CB (2015) Optimal algorithm for the general quay crane double-cycling problem. *Transportation Science* **49**(4):957-967.

Legato P, Trun_o R, Meisel F (2012) Modeling and solving rich quay crane scheduling problems. *Computers and Operations Research* **39**(9):2063-2078.

Meisel F (2011) The quay crane scheduling problem with time windows. *Naval Research Logistics* **58**(7): 619-636.

Sammarra M, Cordeau J-F, Laporte G, Monaco MF (2007) A tabu search heuristic for the quay crane scheduling problem. *Journal of Scheduling* 10:327-36.

Zhu Y, Lim A (2006) Crane scheduling with non-crossing constraint. *Journal of the Operational Research Society*, **57**(12): 1464-1471.

Measurement of port operational performance using data envelopment analysis

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1. Introduction

Global market has expanded rapidly for both goods and services and it contains greater competition and more competitive prices. The majority of this rapid growth of international trade is conducted by maritime transportation. Over 85% of import and export product in global trade is transported through seaports located in a number of countries around the world (Liu 2008). The efficiency of port operations has become one of indicators for nation's economic development and international competitiveness in the international markets. In order to support strongly growing of trade and higher competition between ports, it is essential for port authorities to improve their port performance and efficiency. Consequently, effective evaluation need to be performed to assess operational performance of the port so that to enable each individual port to understand its strengths and weaknesses and be able to establish appropriate business strategies for the competitive environment.

This study applies data envelopment analysis (DEA) to measure operational performance and rank selected sixteen international container ports in Asia and Europe. DEA is a mathematic programming technique for evaluating performance or relative efficiency of a homogeneous set of entities, referred as decision-making units or DMUs which are multiple ports in the study, that consume similar inputs to produce similar outputs (Banker et al. 1984). The method not only accommodates multiple input and output factors from different aspects but these inputs and outputs can also be expressed in different dimensions with different units of measurement (Cooper 2007). This is suitable for evaluating port performance as an operation of port contains multi-dimensional aspects.

DEA is a useful tool for management analysis. The method has been employed in a wide variety of situations for efficiency comparisons. However, the method has a problem of poor discrimination power which many DMUs get efficiency score of one. These DMUs are incomparable with each other when they receive the same ranking. This paper presents a method based on DEA to rank all DMUs by evaluate both efficiency and inefficiency. The efficient and inefficient scores of each port is then combined in order to examine an overall performance of port operation.

2. Methodology

DEA uses linear programming for assessing efficiencies of DMUs. It is designed to measure the efficiencies in situations where the DMUs consume a variety of identical resources or inputs to produce a variety of identical products or outputs. The goal of DEA is to determine the productive efficiency of DMUs by comparing how well the DMU converts inputs into outputs (Charnes et al. 1978). The efficiency score of a particular DMU being evaluated, E_p, is obtained by solving following model.

$$E_p = \max \frac{\sum_r u_r y_{rp}}{\sum_i v_i x_{ip}}$$

$$\text{s.t.} \quad \frac{\sum_r u_r y_{rj}}{\sum_i v_i x_{ij}} \leq 1 \quad \forall j \qquad (1)$$

$$u_r,\ v_i \geq 0 \quad \forall r, i$$

where x_{ij} and y_{rj} are respectively amounts of input ith and output rth of DMU_j, which are in positive number. v_i and u_r are decision variables and are respectively called input and output multipliers or input and output weights. The model can be converted into linear programming version.

$$
\begin{aligned}
& E_p = \max \sum_r u_r y_{rp} \\
\text{s.t.} \quad & \sum_i v_i x_{ip} = 1 \\
& \sum_r u_r y_{rj} - \sum_i v_i x_{ij} \leq 0 \quad \forall j \\
& u_r , \ v_i \geq 0 \quad \forall r, i
\end{aligned} \tag{2}
$$

The basic DEA model does not always provide good result for evaluating performance because it examines only one side or efficiency of DMUs and it frequently gives poor discrimination among DMUs in an assessments. This study proposes a technique to enhance DEA for more efficient computational solution and effective evaluation by combining an evaluation of efficiency and inefficiency of DMUs.

In accordance with the principle of DEA, each DMU is compared with the best performed DMUs which means the DMU that consumes varying amounts of input resources to produce different amounts of outputs is observed only from its efficient or positive side. This study additionally evaluates negative side or weakness of DMUs to explore their performance under adverse circumstances. In opposite to the efficiency score of traditional DEA model, an inefficiency score of an accessed DMU, I_p, can be expressed as a ratio of weighted inputs to weighted outputs. The more resources consumed to produce an amount of outputs, the less efficient is the DMU. This ratio is to be maximized as following mathematical programming, which is an extended model of DEA.

$$
\begin{aligned}
& I_p = \max \frac{\sum_i v_i x_{ip}}{\sum_r u_r y_{rp}} \\
\text{s.t.} \quad & \frac{\sum_i v_i x_{ij}}{\sum_r u_r y_{rj}} \leq 1 \quad \forall j \\
& u_r , \ v_i \geq 0 \quad \forall r, i
\end{aligned} \tag{3}
$$

By using this reverse practice, each DMU is compared with the worst performed DMU and is determined by its negative efficiency. If the optimal objective value I_p satisfies $I_p = 1$, then that assessed DMU belongs to the worst performance group and can be judged to be worst or inefficiency. On the other hand, it rates higher than the worst performed group if $I_p < 1$. DMU has better performance if I_p is closer to zero. An inefficiency score for a particular DMU can be estimated by solving the following linear programming problem.

$$
\begin{aligned}
& I_p = \max \sum_i v_i x_{ip} \\
\text{s.t.} \quad & \sum_r u_r y_{rp} = 1 \\
& \sum_i v_i x_{ij} - \sum_r u_r y_{rj} \leq 0 \quad \forall j \\
& u_r , \ v_i \geq 0 \quad \forall r, i
\end{aligned} \tag{4}
$$

In order to examine all DMUs, the results of the two extreme cases are simultaneously considered by combining efficiency score of each DMU evaluated under favourable circumstance by DEA or E_p with an inverse form of its inefficiency score evaluated under adverse circumstance, I_p. Total score of each DMU, T_p, is calculated by

$$
T_p = E_p + (1 - I_p) \tag{5}
$$

DMU acquiring maximum score among other DMUs regards as having the best operational performance.

3. Result analysis

The methods discussed in previous section is applied to evaluate operational performance with respect to containerized cargoes across sixteen international ports recognized for their high lever performance in terms of throughput in Asia and Europe. This study uses port data and factors referred to the study of Tongzon (2001). The performance of each port is measured with respect to eight factors containing six inputs and two outputs. The outputs are cargo throughput which is measured as the total number of twenty foot container equivalent units loaded and unloaded (TEUs handled) and ship working rate which represents the level and quality of port service by measuring the number of containers moved per working hour (shiprate). To facilitate port operations, a variety of inputs are required to produce the mentioned outputs. Six inputs used in the analysis are number of cranes, number of container berths, number of tugs, terminal area measured in square meter, delay time measured in hour, and labor which is proxied by the number of port authority employees. More detail of input and output factors can be seen in Tongzon (2001). The input and output variables of sixteen ports are shown in Table 1.

Each DMU in Table 1 is calculated by the DEA for both efficient and inefficient sides as explained in section two. Three sets of results obtained for each DMU by the DEA (E_p), inverse form of DEA (I_p), and total score (T_p), are generated and their ranking are also presented in Table 2. In original DEA formulation which calculate the efficiency scores of DMUs, nine out of sixteen ports found to be efficient and have a ranking of 1. Seven ports are identified as inefficient i.e. ports of Fremantle, Melbourne, Osaka, Rotterdam, Sydney, Tanjung Priok, and Yokohama. The performance of ports are incomparable due to the weak discrimination in the result. Similar to the result of DEA, twelve ports calculated from the inverted form of DEA are identified as inefficient by obtaining score of one, while the rest of four ports judged to be efficient i.e. ports of Brisbane, Felixstowe, Hong Kong, and La Spezia.

The results described above show that the DEA methodology cannot provide a good discrimination among DMUs for ranking purposes since a large number of DMUs are identified as efficient in original DEA and inefficient in inverse DEA. The poor discrimination power mostly occurs when the number of DMUs is relatively small compared with the number of input and output variables (Thanassoulis 2001). The study requires a larger number of ports to define the efficiency, however due to data constraints Tongzon (2001) resolved the problem by reducing the number of factors i.e. only one output which is the number of TEUs handled is used. This paper presents an alternative method to rank performance of ports by combining efficient and inefficient scores from DEA and inverse DEA respectively without eliminating any input and output measures in the analysis.

Table 1: Port data

DMU	Port	No. of cranes	No. of berths	No. of tugs	Terminal area	Delay time	Labor	TEUs handled	Shiprate
1	Brisbane	6	3	5	474,000	5.5	200	249,439	21
2	Felixstowe	29	13	3	1,432,000	0.6	1824	2,042,423	56.4
3	Fremantle	5	7	5	273,000	9	498	202,680	13.3
4	Hamburg	52	14	25	3,030,000	0.2	1168	3,054,320	37.2
5	Hong Kong	64	18	24	2,198,300	5	800	13,460,343	45
6	Keelung	23	14	9	339,000	13	690	2,320,397	24
7	La Spezia	8	7	8	270,000	3.7	177	871,100	23.9
8	Melbourne	16	12	6	1,184,100	8	829	904,618	20.8
9	Osaka	24	13	10	1,154,000	4	1070	987,948	32
10	Rotterdam	66	18	15	4,158,000	1.7	981	4,935,616	32
11	Singapore	95	17	12	2,979,211	2.3	978	12,943,900	40
12	Sydney	14	11	3	1,124,500	9.5	635	695,312	22.8
13	Tanjung Priok	10	6	11	310,000	50	1513	1,421,693	18
14	Tilbury	11	4	2	519,000	4.5	750	394,772	32.8
15	Yokohama	41	20	34	1,823,250	6	472	3,911,927	47
16	Zeebrugge	16	9	5	2,311,100	1	21	553,175	36.7

Table 2: DEA results of port operational performance measurement

DMU	Port	Efficiency (E_p)		Inefficiency (I_p)		Total performance (T_p)	
		Score	Rank	Score	Rank	Score	Rank
1	Brisbane	1.0000	1	0.9511	4	1.0489	4
2	Felixstowe	1.0000	1	0.7745	2	1.2255	2
3	Fremantle	0.8252	12	1.0000	5	0.8252	12
4	Hamburg	1.0000	1	1.0000	5	1.0000	5
5	Hong Kong	1.0000	1	0.8942	3	1.1058	3
6	Keelung	1.0000	1	1.0000	5	1.0000	5
7	La Spezia	1.0000	1	0.6911	1	1.3089	1
8	Melbourne	0.5648	16	1.0000	5	0.5648	16
9	Osaka	0.6050	15	1.0000	5	0.6050	15
10	Rotterdam	0.6506	14	1.0000	5	0.6506	14
11	Singapore	1.0000	1	1.0000	5	1.0000	5
12	Sydney	0.7126	13	1.0000	5	0.7126	13
13	Tanjung Priok	0.9858	10	1.0000	5	0.9858	10
14	Tilbury	1.0000	1	1.0000	5	1.0000	5
15	Yokohama	0.8456	11	1.0000	5	0.8456	11
16	Zeebrugge	1.0000	1	1.0000	5	1.0000	5

The results of total performance (T_p) of each port in last column of Table 2 shows that there is more discrimination in the result when combining the calculation of efficient (E_p) and inefficient (I_p) score compared to original DEA method (E_p). Those DMUs found to be efficient in original DEA can now be compared using the results of total performance, whereas the DEA cannot compare results as the DMUs receive the same score and rank. Port of La Spezia obtains highest score therefore is ranked in the first position which is considered having highest performance in port operation, followed by ports of Felixstowe, Hong Kong, and Brisbane. However, five ports namely ports of Hamburg, Keelung, Singapore, Tilbury, and Zeebrugge obtain the same score, therefore they cannot be ranked. And the rest of seven ports are ranked from tenth to sixteenth.

4. Conclusions

An attempt of this study is to provide technique for making comparisons and efficiency ranking across ports by applying the DEA analysis to international ports for which relevant data are available. The proposed technique is a useful measurement of port operational performance. It retains those advantages of the original DEA while improving on the method by measuring both positive and negative sides of port operation, and consequently providing more discrimination in efficiency scores resulting in changes in ranking. This technique illustrated in this paper can be used as guideline to evaluate performance of ports using updated port data for the analysis.

References

Banker, D., Charns, A., and Cooper, W. (1984) Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis. *Management Science*, **30**, 1078-1092.

Charnes, A., Cooper, W.W., and Rhodes, E.L. (1978) Measuring the Efficiency of Decision Making Units. *European Journal of Operational Research*, **2**, 429-444.

Cooper, W.W., Seiford, L.M., and Tone, K. (2007) *Data Envelopment Analysis: Models with Restricted Multipliers*, Springer, NY.

Liu, C.C. (2008) Evaluating the operational efficiency of major ports in the Asia-Pacific region using data envelopment analysis. *Applied Economics*, **40**, 1737-1743.

Thanassoulis, E. (2001) *Introduction to the Theory and Application of Data Envelopment Analysis: A Foundation Text with Integrated Software,* Kluwer Academic Publishers, Boston.

Tongzon, J. (2001) Efficiency measurement of selected Australian and other international ports using data envelopment analysis. *Transportation Research Part A*, **35**, 107-122.

An integrated scheduling of berth and quay cranes with maintenance activities

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1. Introduction

Due to the fast development of container port throughput, in the last two decades, a large amount of research throws light onto the operational management of major container terminal resources including berth, quay cranes (QCs), yard cranes and container trucks. As a kind of critical port resources, the assignment and scheduling of berths and QCs receive most interest in the literature, including berth assignment problem (BAP), QC assignment problem (QCAP). On the observation of the interrelationship of the assignment and scheduling of berths and that of QCs, numbers of studies have focused on the integrated BAP-QCAP problem (Park, 2003; Zhen, 2011; Bierwirth et al., 2015; Zhang et al., 2015). Chang et al. (2010) proposed a dynamic allocation model of the integrated BAP-QCAP problem with multi-objectives, and presented a hybrid parallel genetic algorithm that combined parallel genetic algorithm and heuristic algorithm. Li et al. (2015) study disruption recovery optimization in the integrated BAP-QCAP problem, aiming at maximizing the service quality and minimizing the recovery cost as well. Ma et al. (2015) proposed a two-level genetic algorithm to solve the integrated BAP-QCAP problem in multi-user container terminals.

During the mid-term or long-term running of berths and QCs, we observe via field study that QC maintenance activities are much considered during the resource service planning, including component detection and consumptive material renewals. Some maintenance activities are much time consuming. For example, it often takes over eight hours to change the steel ropes of one QC. During a maintenance activity, the relevant QC itself is unavailable, and its location is also infeasible for vessel berthing as well. This observation implies that the maintenance of one QC may have an influence on the integrated scheduling of berths and QCs. As some industry experts said, regular QC maintenance is so important that there is no substitute for this activity. However, to the best of our knowledge, there are no results on the BAP-QCAP problem considering the maintenance activities of resources. In the area of machine scheduling, the factor of machine maintenance has obtained much attention (Lee, 1999; Lee and Lin, 2001; Chan et al., 2006; Xu et al., 2010; Luo et al., 2015; Ali et al., 2016).

Noticing that the maintenance frequency of berths is much less than that of QCs, we only consider the QC maintenance in this work. So, we study the BAP-QCAP problem with the QC maintenance, and investigate the influence of maintenance in the scheduling of berths and QCs. Due to the fact that most BAP-QCAP models without machine maintenance are already NP-hard or NP-complete, heuristic algorithms for large scale input instances are mainly investigated in the above studies for this case with maintenance activities. In this paper, we investigate the BAP-QCAP problem with QC maintenance. One of our contributions is the mathematical formulation of the problem, and we use CPLEX solver to handle the cases with small instances.

2. Important dates and process

In this work, we study the BAP-QCAP problem with QC maintenance, aiming at minimizing the total turnaround times, i.e., the sum of completion time minus arrival time of each vessel. On the quayside there is a length of berth in line together with as set of QCs, which move along the quayside. In a solution to the considered problem, we need to assign a berth line to each vessel, and the berth line must not be shorter than the vessel. Moreover, a subset of the QCs are also determined for serving the vessel, and the service time of the vessel is equal to the ratio of its workload to the number of the assigned QCs. During the processing of any vessel, its berthing location together with the assignment of the QCs keeps unchanged.

We assume that a proportion of the QCs need regular maintenance, and the start and end times of each maintenance activity are known beforehand. All the QCs keep their relative positions unchanged during the moves. The location along the quayside of each QC for maintenance, if any, is previously determined. Neither the QC nor its location is infeasible for vessel berthing during the maintenance. Following the above assumptions, we present a MIP model for the considered problem. The detailed formulation containing over 40 constraint formulae is to be given in the full version of this work.

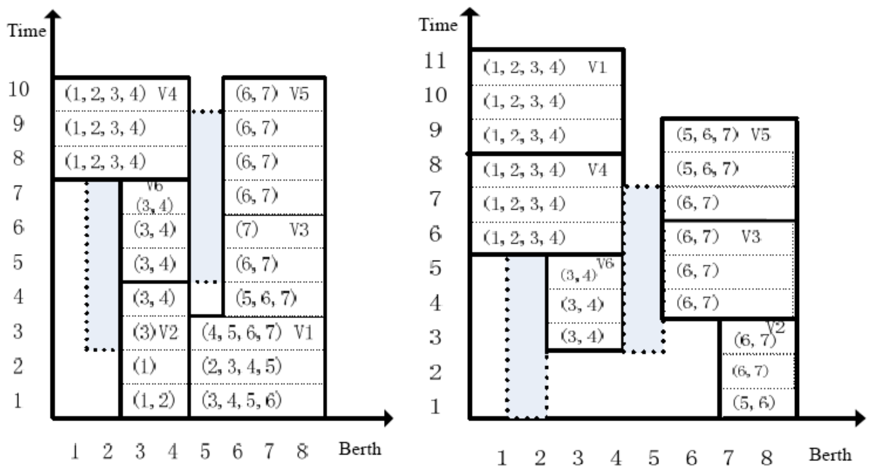
3. Results and conclusions

Below we use CPLEX solver to obtain optimal solutions to small-sized instances. For large-sized cases, CPLEX fails to give feasible or optimal solutions in reasonable time. Therefore, we will present a genetic algorithm for it. We also do comparison on the solution quality and computational efficiency between the proposed algorithm and CPLEX solver in small-sized instances.

We consider the following small instance with six vessels or tasks. The berth line on the quayside is partitioned into eight units of length, and the time horizon is also partitioned into discrete slots, i.e., T=(1,2,3,…). There are six QCs, Q_1, Q_2, Q_3, Q_4, Q_5, Q_6, along the berth line. Each vessel $V_i(a_i, l_i, con_i, q_{min}, q_{max})$ consists of five elements, i.e., its arrival time, length of the vessel, workload, minimum number of required QCs, and maximum number of required QCs, respectively. The information of the six vessels is as follows: SET={V_1(0,4,12,1,4), V_2(0,2,6,1,2), V_3(2,3,6,1,3), V_4(4,4,12,1,4), V_5(1,3,8,1,3), V_6(2,2,6,1,2)}. For example, the second vessel V_2 is released at time 0 and is of 2 units of length, its workload is 6, and the minimum and maximum number of QCs required for serving V_2 is equal to 1 and 2, respectively. Any vessel can only be started for processing in the next time slot after its arrival. For example, V_1 is arrived at time 0 and then it starts processing not earlier than time 1.

The second and fifth QCs Q_2 and Q_5 are planned for maintenance in time horizon. Consider the following two cases on the two QCs' maintenance time intervals: in Case 1, the maintenance time intervals for Q_2 and Q_5 are [1,5] and [3,7], respectively; and in Case 2, the two time intervals are [3,7] and [5,9], respectively. For example, in Case 1, Q_2 is unavailable during time slots 1,2,3,4 and 5.

Given the above example, Figure 1 is an illustration of the optimal solutions for the two maintenance cases. In the figure, the horizontal axis is the discrete berths, and the vertical axis represents the discrete time slots. Each rectangle with thick line represents a vessel. The numbers in each bracket denote the indices of the QCs processing the vessel in the time slot. For example, in the left figure for Case 1, vessel V_4 is being processed by Q_1, Q_2, Q_3 and Q_4 in time slot 10. Each shadowed rectangle with dotted line represents a maintenance activity. According to the figure, in Case 1, V_1 and V_2 are the first processed vessels, while V_4 and V_5 are the last two vessels completed at the end of time slot 10. The objective value is equal to (3-0)+(4-0)+(6-2)+(10-4)+(10-1)+(7-2)=31. With similar analysis, the total flow time in Case 2 is equal to 33. It can be observed that the scheduling as well as the objective value is different in the two cases. We conclude that the optimal scheduling on berth and QCs changes greatly with different planned maintenance time intervals.



(a) Case 1 (b) Case 2

Fig. 1 An illustration of the optimal solution in the example.

References

A G Ali, G Finke , M L Espinouse (2016) Parallel machine scheduling with maintenance: praising the assignment problem, *European Journal of Operational Research*, published online.

C Bierwirth and F Meisel (2015) A follow-up survey of berth allocation and quay crane scheduling problems in container terminals, *European Journal of Operational Research*,

244(3), 675-689.

F T S Chan, S H Chung, L Y Chan, G Finke, M K Tiwari (2006) Solving distributed FMS scheduling problems subject to maintenance: Genetic algorithms approach. *Robotics and Computer Integrated Manufacturing*, **22**(5-6), 493-504.

D F Chang, Z H Jiang, W Yan, J L He (2010) Integrating berth allocation and quay crane assignments, *Transportation Research Part E*, **46**(6), 975-990.

C Y Lee (1999) Two-machine flowshop scheduling with availability constraints, *European Journal of Operational Research*, **114**(2): 420-429.

C Y Lee, C S Lin (2001) Single-machine scheduling with maintenance and repair rate-modifying activities, *European Journal of Operational Research*, **135**(3): 493-513.

M Z Li, J G Jin, C X Lu (2015) Real-Time Disruption Recovery for Integrated Berth Allocation and Crane Assignment in Container Terminals, *Transportation Research Record*, 2479, 49-59.

W C Luo, T Cheng, M Ji (2015) Single-machine scheduling with a variable maintenance activity, *Computers & Industrial Engineering*, **79**, 168-174.

H L Ma, F T S Chan, S H Chung (2015) A fast approach for the integrated berth allocation and quay crane assignment problem, *Proceedings of the Institution of Mechanical Engineers Part B-Journal of Engineer Manufacture*, **229**(11), 2076-2087.

Y M Park and K H Kim (2005) A scheduling method for Berth and Quay cranes, *Container Terminals and Automated Transport Systems*, 159-181.

D Xu, Y Yin, H Li (2010) Scheduling jobs under increasing linear machine maintenance time, *Journal of Scheduling*, **13**(4), 443-449.

R Zhang, Z H Jin , Y Ma, W X Luan (2015) Optimization for two-stage double-cycle operations in container terminals, *Computers & Industrial Engineering*, **83**, 316-326.

L Zhen, E P Chew, L H Lee (2011) An Integrated Model for Berth Template and Yard Template Planning in Transhipment Hubs, *Transportation Science*, **45**(4), 483-504.

16:00 – 18:00	Session 2B (Floor 16) Theme: Maritime (Water freight)	Chair: Thalis Zis

The Potential for Water Freight in the South West UK
Sapna Chacko, Michael Roe and John Dinwoodie

The Cargo Fare Class Mix Problem Extended
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THE POTENTIAL FOR WATER FREIGHT IN THE SOUTH WEST UK

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1 Purpose

The importance of water freight as a sustainable mode of transport is growing continuously. As world trade depends on maritime transport, water transportation has a special place in the logistics industry. Water transportation is a sustainable mode of transport in a supply chain. Today, rising environmental concerns encourage business to seek alternatives from road transport, and have renewed the interest in waterborne transport. The integration of water freight in to intermodal transportation and logistics will increase the efficiency and competitiveness of the freight transport industry while maintaining an environmental balance (Tailor, 1993). Water freight offers many environmental and financial advantages to society (Yassin et al, 2010). This research investigates the potential for water freight (short sea shipping, coastal shipping and inland shipping) in the South West UK especially in Devon and Cornwall. The study aims to identify current practices in water freight, the importance of water as a mode of transport in the supply chain, the logistical, economic and environmental benefits of using water freight as a mode of transport, its socio-economic impact in society, challenges blocking the successful management of water freight and to identify whether the use of water freight as a mode of transportation is worthwhile to the logistics industry in Devon and Cornwall.

2 Research Approach

A conceptual model was developed based on the research objectives and literature review on water freight. A conceptual model links the objectives of the research, literature review and issues which should arise from the literature review and brings out interrelationships among them, which inevitably leads to the formation of the most suitable methodology for making solutions for the issues (Miles et al, 2014). It helped to recognise all important key factors and their assumed interrelationships to analyse the present situations in water freight. Simultaneously the formation of a conceptual model led to the realization of the most suitable methodology for accomplishing the objectives of the study. The management of water transportation in the supply chain to achieve various logistical, economic and environmental advantages depend upon the efficient and effective interrelationship among the key factors. The key factors identified in the conceptual model are port infrastructure and hinterland connections, professionals in the industry, stakeholders, policy, support and promotion from the government, the European Union and the Department for Transport, weather and tidal constraints, tax incentives and subsidies and market demand for water freight. Since water freight in Devon and Cornwall has been less studied than many other parts of the UK, the opinions and suggestions from the experts in the shipping and logistics field on the management of existing and future of water freight is very important to achieve the objectives of the study. The best way identified to approach for the experts' observations and recommendations on the research topic as per the conceptual model is the Delphi method. Thus the Delphi method is used for primary data collection. It uses recursive rounds of sequential surveys interspersed with controlled feedback reports and the interpretation of experts' opinion to organize conflicting values and experiences in to consensus (Donohoe et al, 2012).

The research completed three rounds of the Delphi survey. As explained before the limited usage of water transportation in Devon and Cornwall forced the researcher to gather a high level of consensus on each statement to get a real picture of water transportation in the region. Thus the consensus level was fixed at 75%.

A focus group with the members of the 'Maritime and Waterborne Innovation Group' in the South West UK was conducted to measure the trustworthiness of the Delphi findings on the potential for water freight in the South West UK. Establishing the methodological rigour of the Delphi study is a vital aspect of this research to produce dependable results. Focus group as a secondary method helps to provide an interpretative aid to research findings, contextual basis for research methods, and generating new insights on the early findings of a research (Bloor et al, 2001). The verification of Delphi findings will clarify and strengthen, help to gauge the generalizability or transferability of the findings (Hansson and Keeney, 2011).

Five members of the Maritime and Waterborne Innovation Group' in the South West UK were participated in the focus group. They discussed many aspects of the Delphi results on the potential for water freight in the South West UK for 90 minutes. Also focus group participants shared their experiences, opinions, wishes and concerns about water freight in the region.

3 Findings

The Delphi study achieved a total of eight statement consensuses among the expert panel members. The consensuses were; 1) the presence of an extensive coast line and accessibility to a number of ports along the coast of the South West UK are supportive for the effective management of water freight movements in the region. 2) Water freight is a sustainable green alternative to road and rail. 3) Water freight is more labour, energy and fuel efficient than road transport. 4) As an efficient and sustainable mode of transport, water fright will reduce the cost of transportation of bulk products over long distances. 5) It helps to minimise overland congestion, negative impacts on the environment, and external costs. 6) It provides competitive cost, integration across all regions, economic progress and sustainability compared to road transport. 7) At present ports in Devon and Cornwall lack investments in infrastructure and poor hinterland connectivity blocks the well-organized and profitable management of water freight in the region. 8) As a result, the integration of water freight in the logistics chain is difficult.

Meanwhile the statements which almost achieved agreement (70-74%) among the expert panel members confirmed that the potential of water freight as the mode of transport is facing many problems to utilize its full potential due to insufficient port infrastructure and hinterland connectivity in the region. Professionals related to the industry need more information about the possibilities of water freight to prepare themselves for the better management of water freight in Devon and Cornwall. With the help of improved resources water freight in the region can support transfer of road freight movements to water and will be beneficial to the economy of Devon and Cornwall.

The focus group discussion presented a detailed analysis of the Delphi results. According to focus group participants, water freight in the South West UK is facing many issues to utilize its maximum potential. Main issues are poor hinterland connectivity and infrastructure at the ports, competition from road and rail in terms of cost, small population in the region, no substantial ports between Land End and Southampton and limitations in terms of tidal access because of very high rise and fall of tide. Many suggestions were formed during the focus group discussion for the development of water freight in the South West UK. The option for a feeder service, building part of the harbour out into the estuary enables the all tide accessibility, use of small ships, small ports and harbours for small businesses, demand positioning within Devon and Cornwall, identify ports which can be invested in deepening and expanding berths, cranes and all other infrastructure are some of the recommendations to develop water freight in the region. The focus group participants also discussed about issues require further exploration for the development of water freight in the South West UK. The main areas which need further investigation are; to collect data such as shipping cost, worldwide cargo in containers to place in Devon and Cornwall and the other way around, how many people are actually shipping in and out and opportunities through feeder traffic can be generated in the region.

4 Discussion and conclusion

The three rounds of Delphi surveys together brought a large amount of information on water freight in the South West UK especially in Devon and Cornwall. Water freight is best suited to transport non-time critical bulk cargoes. Small and medium ports in the region can be used for small quantities of single bulk cargo movements. With the integration of local water freight into intermodal transportation, links between the existing port facilities, better hinterland connections, infrastructure and operational systems, the management of water transportation would be much easier to perform. The administration of water transportation can be supported by the introduction of subsidies, grants and a reduction in duty/taxes for water freight as a sustainable mode of transport. Better water freight movements will reduce road congestion, increase port employment, and local jobs and local distribution opportunities which could be beneficial to industry and society. The use of water freight will produce a better environment, congestion free roads, integration of remote locations, less price for goods, and a better economy.

This study reveals the latest information about waterborne freight in Devon and Cornwall. The data collected during the Delphi study helped to realize the importance of using water freight and possibilities of it in South West UK. It was identified that water transportation is a sustainable mode of transport and offers many benefits to industry, society and environment. However the usage of water freight in the South West UK is low due to many reasons. The major reason for low usage is the lack of infrastructure at the ports and hinterland connectivity. The expert panel members shared information on water freight from their experience and knowledge accumulated from the industry over many years. The findings of the study will be useful for the government departments working for freight transportation, and shipping and logistics industry to develop better management strategies to increase the usage of water transportation in the region. Results of the research provide many practical recommendations to encourage the logistics industry to successfully manage water freight for the movement of goods, services and information without disturbing the environment. The Delphi study reveals when waterways are used for transportation, the economy and social status of that particular region will be improved. Thus this study opened a new insight into the possibilities and innovative uses of less considered waterways as a sustainable mode of transport in the coming days.

The focus group discussion presented a very good interpretation of the Delphi results. The participants of the focus group collectively have 198 years of experiences in the shipping and logistics industry. Their experiences, knowledge, expectations, visions and concerns about water freight in the South West UK have contributed to the justification of the Delphi results. Their suggestions for policy formulation for the development of water freight in the region, barriers to policy formulation and implementation, and issues need further investigation for the development of water freight in the region were clearly identified in the focus group. They pointed out many issues in the progression of water freight, factors favourable for water freight development, opportunities available in the region and role of local, regional and national authorities in promoting water freight in the South West UK. A discussion on the policies for the development of water freight recognised that there is a little bit open attitude from the government side in the promotion of maritime activities. At the same time stereo thinking and inertia from local authorities create problems in the increased usage of water freight. An analysis of the barriers to policy implementation in promoting water freight in the region recognised the lack of understanding of the sector at the regional level, lack of entrepreneurial activities in the South West UK and limited commercial knowledge about exactly how much money the freight could be generated, prevent proper implementation of policies. As a result of an in-depth focus group discussion generated new insights on the early findings of the Delphi study and helped to strengthen the Delphi results generalizability and transferability.

The results of this research also have many implications to the rest of the world where water freight is in the developing stage or aiming to increase the usage of it. The suggestions, observations and information collected during the Delphi study and from the focus group participants could be used for forming better management strategies to improve the efficiency and effectiveness of water transportation in a region or country. Consequently the economic and environmental benefits of using water freight would be more real in the shipping and logistics industry and society.

References

Bloor, M., Frankland, J., Thomas, M., and Robson, K. (2001) *Focus Group in Social Research*. Sage Publications. 1st Edition. London

Donohoe. H, Stellefson. M, and Tennant. B. (2012). Advantages and limitations of the e-Delphi technique. *American Journal of Health Education*, 43(1), pp. 38-46.

Hasson. F, Keeney. S. (2011), Enhancing rigor in the Delphi technique research, *Technological Forecasting & Social Change*, 78, pp. 1695-1704

Miles. M. B., Huberman. A. M and Saldana. J. (2014). *Qualitative Data Analysis*. Sage Publications, 3rd Edition, London

Tailor, J. (1993). Remove barriers to intermodal, *Transportation and distribution*, 34(4), p. 34.

Yassin, S. M., Shaffril, H. A.M., Hassan, M. S., Othman, M.S., Samah, A.A., and Samah, B. A. (2010), Prospects of Waterway Development as a Catalyst to improve Regional and community Socio-Economy Level, *American Journal of Economics and Business Administration*, 2(3), pp. 240-246.

The Cargo Fare Class Mix problem extended

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1 Introduction

The enormous growth in the size of deep sea containers vessels causes peak loads on terminals and hinterland connections (Saanen, 2013). Due to physical restrictions the capacity of hinterland connections for container transportation cannot keep up with this growth in container liner shipping. Simultaneously, port authorities put restrictions on the modal split of the connections to the deep sea port, favourable towards intermodal connections (rail and barge), e.g. in Rotterdam (Port of Rotterdam, 2010), Hamburg and Antwerp (Van den Berg and De Langen, 2014). To accommodate the peak loads from terminals and meet the modal split targets, the inland transportation network needs to become more efficient.

With traditional planning methods (see an overview in SteadieSeifi *et al*, 2014), this efficiency gain is not possible, as customers place transportation orders with strict planning restrictions, allowing little options for optimising the network. They are hesitant to allow a transportation network operator to select a transportation mode, route and time (Van Riessen *et al*, 2015-a). For efficient network optimisation, a mind shift among transportation customers is required (Van der Horst and De Langen, 2008).

Our research shows that by offering a differentiated portfolio of transportation services with varied service levels and fares, different customer segments can be targeted with incentives for allowing planning flexibility to the network operator. The key is to find the optimal balance between the fare class sizes. The concept of different service propositions in transportation is very similar to the concept of different fare classes for a flight in passenger air travel. Barnhart *et al* (2003) give an overview of operations research in airline revenue management. The primary objective of airline revenue management models is to determine the optimal fare mix: how many seats of each booking class should be available, given demand forecasts and limited total number of seats? Since the introduction of revenue management on a single flight (Littlewood, 1972) and in an aviation network (Glover *et al*., 1982), many studies have considered the passenger fare class mix problem. For an overview, see McGill & Van Ryzin (1999). More recent work on airline revenue management focuses mostly on airline alliances and competition (Wright *et al.*, 2010), which is not (yet) relevant for the inland transportation system. The main difference between the fare class mix problem for passengers and for cargo, is that the possibilities for the network operator of changing a passenger route are much more limited than for changing the routing of cargo. Typically, in passenger transportation routing cannot be changed, although sometimes upgrades to a higher quality product can be considered (Steinhardt *et al.*, 2012). In contrast, in revenue maximisation for cargo transportation, the routing of accepted bookings can be changed, as long as agreed delivery windows are met. So far, existing approaches for optimising revenue in cargo transportation consider only one booking limit for one fare class (Chopra and Meindl, 2014, Liu and Yang, 2015), or only consider the operational problem of accepting or rejecting incoming orders (Bilegan *et al,* 2013). Our approach aims at the tactical decision problem for a differentiated fare class mix. We show that an optimal fare class mix can significantly increase revenue for the transportation provider, compared to existing methods. Our main purpose is to show that an optimal fare class mix of products differentiated by fare class and lead-time can significantly improve network capacity utilisation and profit, compared to the traditional approach in literature to focus on maximising sales of a premium product.

In Van Riessen, *et al* (2015-b) we introduced the class of Cargo Fare Class Mix (CFCM) problems, for determining optimal booking limits for two fare classes. We proposed a formulation for the CFCM (1,1,2) problem, considering a corridor with one route and one destination for which 2 products are offered. The proposed formulation is non-linear and only suitable for single corridor situations with two fare classes. In this work we aim to extend this model, by proposing a MILP version of the CFCM (1,1,2) problem and propose solution methods for more elaborate problems. Our interest goes beyond providing a solution model for specific demand scenarios, and aims to explore the general structure of an optimal fare class mix with booking limits for each fare class considering stochastic demand distributions per fare class. The CFCM problem has applications in liner shipping, parcel delivery, web shop inventory management, but we show the application in the context of intermodal container transportation.

2 Modeling framework

In the CFCM problem, the transportation provider's goal is to maximise revenue by finding the optimal balance in offered transportation services, each service denotes a *fare class*. A fare class is characterised by a specific price and specific lead time, ranging from a high price fast service to a low price slow service. The optimal balance maximises revenue by selling a feasible amount of high priced services, supplemented with lower priced services with more planning flexibility to compensate for demand volatility and to attain a high utilisation of transportation capacity. The CFCM problem class has many dimensions (Van Riessen, 2015-b). The operational planning problem considers multiple routes r and multiple destinations d for transporting all cargo. This must be done within the time limits of the product agreed on with the customer; the number of fare classes p is the third dimension. We use these dimensions to classify the problem type of the CFCM problem as CFCM (r, d, p). Because the intermodal transportation problem is mostly related to one deepsea port, we do not distinguish between multiple origins. We use these dimensions to denote the problem type of the CFCM problem as CFCM (r, d, p), as shown schematically in Figure 1.

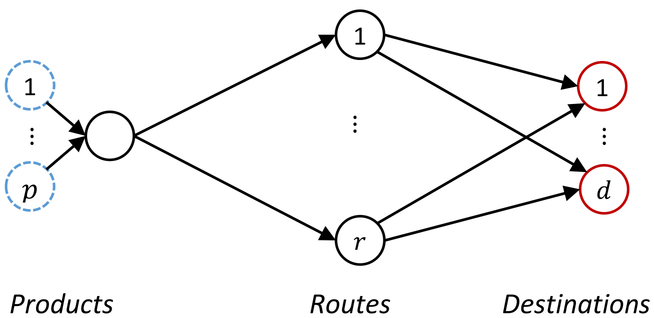

Figure 1: Schematic model of the Cargo Fare Class Mix problem with r routes, d destinations and p fare classes, CFCM (r,d,p) (Van Riessen et al, 2015-b).

Finally, we need to distinguish between deterministic or stochastic fare class limits. With deterministic daily limits, the maximum accepted demand for each day is determined by the fare class limits. Alternatively, if long-term contracts with delivery requirements are agreed on a monthly or weekly basis, the accepted demand per day is not determined by deterministic fare class limits, but by the mix of accepted long-term contracts. Note that in either case, the demand pattern is stochastic.

The expected accepted demand per offered fare class s is denoted by $\mathbb{E}(D_s)$, in which D_s is the market demand N_s capped by booking limit L_s.

$$D_s = \min(N_s, L_s).$$

We assume a revenue f_s for all accepted order of fare class s. The expected transport volume on route r is denoted by $\mathbb{E}(T_r)$, and the expected excess volume, which was accepted but cannot be not transported is denoted by $\mathbb{E}(E_s)$. For each order transported on route r, we consider a transportation cost c_r, irrespective of the fare class of that order. Finally, excess demand of class s must be penalized by p_s. The general objective of the CFCM (r, d, p) problem is to maximise expected profit margin, i.e. expected revenue minus the costs for carrying out transportation and penalties for not fulfilling accepted transportation requests:

$$\max_{L_s} J = f_s\mathbb{E}(D_s) - c_r\mathbb{E}(T_r) - p_s\mathbb{E}(E_s), \tag{1}$$

subject to constraints on timing, routing to the correct end destination, capacity and equilibrium equations for the steady state of the expected values.

3 The contribution

The presented framework and current state of the model development will be fully presented. We aim to provide an explicit MILP formulation for the CFCM (1,1,2) problem. Such a linear formulation does not exist yet and allows finding the optimal fare class mix in larger instances. Also, we will present considerations on how to expand to a formulation of the CFCM (r,1,2) problem (schematically depicted in Fig. 2), i.e. a model for finding the optimal balance between two transportation products in a network formulation, considering multiple routes from one origin to one destination. Initial results show that the policy of how to assign an order of a fare class to a suitable route has a huge impact on the expected profit margin.

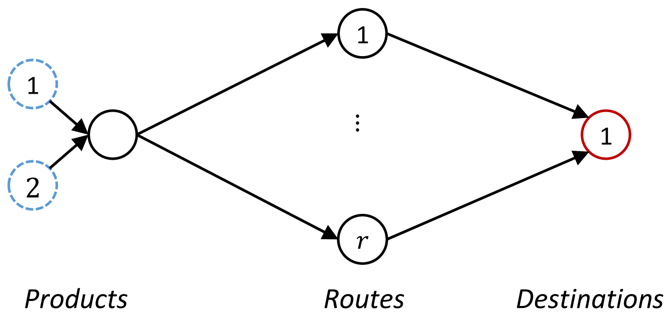

Figure 2: Schematic model of the Cargo Fare Class Mix problem with r routes, 1 destination and 2 fare classes, CFCM (r,1,2)

References

Bilegan, I. C., Brotcorne, L., Feillet, D., & Hayel, Y. (2013). Revenue management for rail container transportation. *Journal on Transportation and Logistics*, 4(2), 261-283.

Chopra, S., & Meindl, P. (2014). Allocating capacity to multiple segments. In *Supply chain management. International Edition*. (pp. 486). Pearson Education Limited.

Glover, F., Glover, R., Lorenzo, J., & McMillan, C. (1982). The passenger-mix problem in the scheduled airlines. *Interfaces*, *12*(3), 73-80.

Littlewood, K. (1972). Forecasting and Control of Passenger Bookings, AGIFORS 12th Annul Symposium Proceedings. *October, Nathanya, Israel*, 193-204.

Liu, D., & Yang, H. (2015). Joint slot allocation and dynamic pricing of container sea–rail multimodal transportation. *Journal of Traffic and Transportation Engineering*, 2(3), 198-208.

McGill, J. I., & Van Ryzin, G. J. (1999). Revenue management: Research overview and prospects. *Transportation science*, *33*(2), 233-256.

Port of Rotterdam (2011, December 15). *Port Vision 2030*. Available from: https://www.portofrotterdam.com/en/the-port/port-vision-2030.

Saanen, Y. (2013), "Mega-ships: positive assets or terminals' worst nightmare?", Port Technology International, May 2013

SteadieSeifi, M., Dellaert, N. P., Nuijten, W., Van Woensel, T., and Raoufi, R. (2014). Multimodal freight transportation planning: A literature review. *European Journal of Operational Research*, 233(1), 1-15.

Steinhardt, C., & Gönsch, J. (2012). Integrated revenue management approaches for capacity control with planned upgrades. *European Journal of Operational Research*, *223*(2), 380-391.

Van den Berg, R., and De Langen, P. W. (2014). An exploratory analysis of the effects of modal split obligations in terminal concession contracts. *International Journal of Shipping and Transport Logistics*, 6(6), 571-592.

Van Der Horst, M. R., and De Langen, P. W. (2008). Coordination in hinterland transport chains: a major challenge for the seaport community. *Maritime Economics & Logistics*, 10(1), 108-129.

Van Riessen, B., Negenborn, R. R., & Dekker, R. (2015-a). Synchromodal container transportation: an overview of current topics and research opportunities. In *Proceedings of the 6th International Conference on Computational Logistics* (ICCL'15), Delft, The Netherlands, pp. 386-397. Springer.

Van Riessen, B., Negenborn, R. R., & Dekker, R. (2015-b). *The cargo fare class mix problem - revenue management in synchromodal container transportation*. Manuscript in preparation. http://dx.doi.org/10.13140/RG.2.1.4894.9841.

Wright, C. P., Groenevelt, H., & Shumsky, R. A. (2010). Dynamic revenue management in airline alliances. *Transportation Science*, *44*(1), 15-37.

The impact of canvasser and bargaining agent on equilibrium structure of maritime service supply chain

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1. Introduction

Ocean shipping and inland feeder service are complementary products in maritime industry. Unlike the general supply chain with complementary product, canvasser problem is a characteristic feature with great practical value in maritime supply chain. For example, consider a shipping company such as Maersk Line, who provides ocean shipping service and simultaneously, the freight forwarder service. Similarly, a freight forwarder company such as SINOTRANS, provides freight forwarder service and inland feeder service. Therefore for customer, both Maersk Line and SINOTRANS can act as canvasser. They compete for demand, while one purchases the other's transportation service when being canvasser, and cooperate to provide full-service transport solution in supply chain.

Furthermore, the alliance tendency of shipping line undoubtedly strengthen the relative status and bargaining power of shipping company in maritime supply chain. In order to strive for higher quoted price, the inland feeder service supplier tend to establish alliance, such as SINOTRANS and Chu Kong Inland Freight Terminal Company, ally via cross-shareholdings among serval inland terminals in Pearl River Delta region in China. Meanwhile, bargaining agent is another alliance form that widely practiced with a revenue sharing contract. For example, maritime industrial organization or outsourcing intermediary, however, price discrimination also commonly exists. The different canvasser and bargaining agent practices motivate us to ask the following research questions: Is it more profitable to be canvasser for shipping company and forwarder? What is the interaction between canvasser and bargaining agent decision? What is the equilibrium structure? What is the effect of canvasser and bargaining agent decision on channel profit?

To address these questions, we introduce four scenarios, i.e., shipping company as canvasser and forwarders do not ally, forwarders as canvasser and they do not ally, shipping company as canvasser and forwarders ally, forwarders as canvasser and they ally. The forwarders ally via bargaining agent and a revenue sharing contract between them is introduced. We focus on the optimal strategies of shipping company and forwarders and derive the value of equilibrium structure.

The highlights of this paper can be summarized as follows. We are the first to investigate the joint canvasser and bargaining agent decision problems which are widely practiced in maritime industry. We characterize the optimal solution and provide insightful strategies for shipping company and forwarders. We derive the value of the joint canvasser and bargaining agent decision effect on equilibrium structure and channel structure profit.

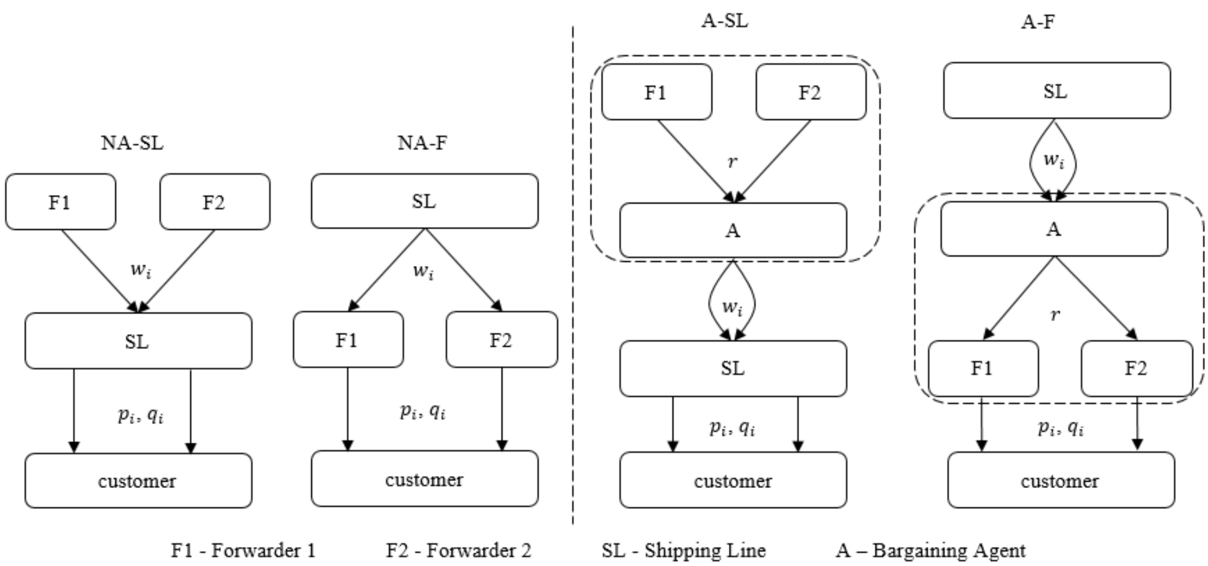
2. Model and methodology

Consider a shipping company such as Maersk Line provides ocean shipping service and two upstream forwarders such as SINOTRANS provide inland feeder service, also these three companies could act as canvasser which provide freight forwarder service, we focus on the optimal strategies and supply chain equilibrium structure. We use the following natation for easy reference.

a : Base market potential (maximum attainable under no cross-effects).
b : Cross demand sensitivity of price.
c : Transportation cost of the ocean shipping line.
r : Revenue sharing rate.
w : Wholesale price.
p : Retail price.
q : Demand (aka retail quantity).
Π_{F1}, Π_{F2} : Profit of forwarder 1 and 2.
Π_A : Profit of bargaining agent.
Π_S: Profit of shipping company.

Note that upper case superscripts A-SL, A-F, NA-SL and NA-F, if added to the above notation, refer to the optimal solutions in scenario A-SL, A-F, NA-SL and NA-F, respectively, and subscript $i \in \{1,2\}$ refer to the supply chain in each scenario.

As mentioned above, we first introduce two models, i.e., model with and without bargaining agent. Then in each model we consider two scenario, i.e., shipping company as canvasser and forwarders as canvasser. Thus we introduces four scenarios to characterize the canvasser and bargaining agent problem. As we can see in Figure 1(a) without bargaining, scenario NA-SL means the shipping company as canvasser and the forwarders do not ally; scenario NA-F means the forwarders as canvasser and simultaneously they do not ally. While in Figure 1(b) with bargaining agent, scenario A-SL means the shipping company as canvasser and the forwarders ally; scenario A-F means the forwarders as canvasser and simultaneously they ally. Meanwhile, a revenue sharing contract is introduced between the bargaining agent and forwarders. Thus, comparison of these four scenarios help deriving the value of optimal strategies and equilibrium structure.



(a) without bargaining agent *(b) with bargaining agent*

Figure 1: Model structure

Due to the canvasser problem, we consider the quantity competition thus the demand function for each supply chain can be expressed as following:

$$p_i(q_i, q_j) = a - q_i - bq_j.\text{ for } i, j = 1,2 \text{ and } i \neq j. \quad (1)$$

This type of demand function is commonly used in the literatures to measure quantity competition in transportation service industry (Mantin, 2012; Álvarez-SanJaime et al., 2015). a is the base market potential and it is required to be equal in two chains, the demand substitution coefficient b that measures the degree of substitution demand effect, in range [0,1].

3. Results and conclusions

3.1 Effect of canvasser

Lemma 1. Comparison between shipping company as canvasser and forwarders as canvasser without bargaining agent yields ($B_1 \approx 0.849, B_2 \approx 0.746$)

(a)$\Pi_{F1}^{NA-SL} \geq \Pi_{F1}^{NA-F}, \Pi_{F2}^{NA-SL} \geq \Pi_{F2}^{NA-F}$, if $b \in (0, B_1]$

$\Pi_{F1}^{NA-SL} < \Pi_{F1}^{NA-F}, \Pi_{F2}^{NA-SL} < \Pi_{F2}^{NA-F}$, if $b \in (B_1, 1]$

(b)$\Pi_{SL}^{NA-SL} \leq \Pi_{SL}^{NA-F}$, if $b \in (0, B_2]$

$\Pi_{SL}^{NA-SL} > \Pi_{SL}^{NA-F}$, if $b \in (B_2, 1]$

Lemma 2. Comparison between shipping company as canvasser and forwarders as canvasser with bargaining agent yields

(a)$\Pi_{F1}^{A-SL} \geq \Pi_{F1}^{A-F}, \Pi_{F2}^{A-SL} \geq \Pi_{F2}^{A-F}$

(b)$\Pi_{SL}^{A-SL} \leq \Pi_{SL}^{A-F}$

Consider joint Lemma 1 and Lemma 2, first without bargaining agent, if $b \in (0, B_2]$, both shipping company and forwarders do not want to be canvasser, a conflict occurs; if $b \in (B_2, B_1]$, both shipping company and forwarders prefer shipping company to be canvasser; if $b \in (B_1, 1]$, both shipping company and forwarders prefer to be canvasser and compete in demand. On the other hand with bargaining agent, however, both shipping company and forwarders do not want to be canvasser in this scenario.

3.2 Impact of bargaining agent

Theorem 1. Compared to the optimal profit of shipping company between with and without bargaining agent, the following inequalities hold:

(a)$\Pi_{SL}^{NA-SL} > \Pi_{SL}^{A-SL}$.

(b)$\Pi_{SL}^{NA-F} > \Pi_{SL}^{A-F}$.

Lemma 3. Compared to the optimal profit of forwarders between with and without bargaining agent under shipping company as canvasser, the following inequalities hold:

(a)$\Pi_{F1}^{NA-SL} \geq \Pi_{F1}^{A-SL}, \Pi_{F2}^{NA-SL} \geq \Pi_{F2}^{A-SL}$, if $b \in \left(0, \frac{2\sqrt{r}}{1+\sqrt{r}}\right]$.

(b) $\Pi_{F1}^{NA-SL} < \Pi_{F1}^{A-SL}, \Pi_{F2}^{NA-SL} < \Pi_{F2}^{A-SL}$, if $b \in \left(\frac{2\sqrt{r}}{1+\sqrt{r}}, 1\right]$

Lemma 4. Compared to the optimal profit of forwarders between with and without bargaining agent under forwarders as canvasser, the following inequalities hold:

(a)$\Pi_{F1}^{NA-F} \geq \Pi_{F1}^{A-F}, \Pi_{F2}^{NA-F} \geq \Pi_{F2}^{A-F}$, if $r \in \left(0, \frac{1}{9}\right]$ and $b \in \left(0, \frac{2\sqrt{r}}{1-\sqrt{r}}\right]$, or $r \in \left[\frac{1}{9}, 1\right)$.

(b)$\Pi_{F1}^{NA-F} < \Pi_{F1}^{A-F}, \Pi_{F2}^{NA-F} < \Pi_{F2}^{A-F}$, if $r \in \left(0, \frac{1}{9}\right)$ and b $\in \left(\frac{2\sqrt{r}}{1-\sqrt{r}}, 1\right]$

From Theorem 1 we conclude that, no matter who is the canvasser, alliance of forwarders leads to a profit loss of shipping company. Consider joint Lemma 3 and Lemma 4, if $r \in \left(0, \frac{1}{9}\right)$ and $b \in \left(\frac{2\sqrt{r}}{1+\sqrt{r}}, 1\right]$, forwarders choose to ally for higher profit; if $b \in \left(\frac{2\sqrt{r}}{1+\sqrt{r}}, \frac{2\sqrt{r}}{1-\sqrt{r}}\right]$, the forwarders ally when themselves as canvasser and do not ally when shipping company as canvasser; if $b \in \left(0, \frac{2\sqrt{r}}{1+\sqrt{r}}\right]$, the forwarders will never choose to ally.

3.3 Equilibrium structure

Theorem 2. There exist three equilibrium solutions which are presented as follows:

(1) When $r \in \left(0, \frac{1}{9}\right]$ and $b \in \left(0, \frac{2\sqrt{r}}{1-\sqrt{r}}\right]$ and $b \in (0, B_2]$, or $r \in \left[\frac{1}{9}, 1\right)$ and $b \in (0, B_2]$, the equilibrium is "NA-F", forwarders as canvasser and they do not ally.

(2) When $b \in (B_2, 1]$ and $b \in \left(0, \frac{2\sqrt{r}}{1+\sqrt{r}}\right]$, the equilibrium structure is "NA-SL", shipping company as canvasser and forwarders do not ally.

(3) When $b \in \left(\frac{2\sqrt{r}}{1-\sqrt{r}}, 1\right]$, the equilibrium structure is "A-F", forwarders as canvasser and they ally.

According to the Theorem 2, the solution set of equilibrium solution can be presented as Figure 2 shows. Compared to the optimal profit of shipping company and forwarders in each set, however, it is worth to note that the equilibrium "A-F" is always lead to the worst profit of shipping company and forwarders, since the set "None" is never a Nash equilibrium, Theorem 2 suggests that the classical Prisoner's Dilemma Occurs.

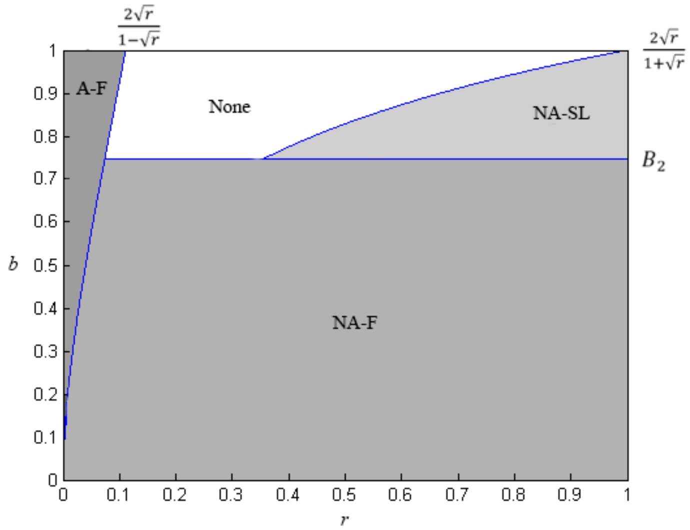


Figure 2: Equilibrium structure

References

B Mantin (2012) Airport complementarity: Private vs. government ownership and welfare gravitation, *Transportation Research Part B: Methodological*. **46**(3), 381-388.

Ó Álvarez-SanJaime, P Cantos-Sánchez, R Moner-Colonques, J J Sempere-Monerris, (2015) The impact on port competition of the integration of port and inland transport service, *Transportation Research Part B: Methodological*, **80**, 291-302.

Analytical Model to Measure Sea Cargo Export Demand in Sri Lanka

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1. Introduction

The export sector of Sri Lanka plays a very important role in economic development as well as in social development. Increasing the export revenue of the country is a way to improve the international trade performance, which may ultimately lead to the economic development. Creation of employment opportunities through the improvement of export sector can direct the country for social development. The effort of improving the export performance is a long term continuous process which is influenced by many economic factors. Majority of the export revenue of Sri Lanka is generated by the exports that leave the country through maritime leg. It is important to analyse and model the sea exports separately because, the objectives of the exporters involved with sea transport are different from the exporters using the air transport.

2. Methodology

The first objective of this research is to identify and study the trend of the export cargo categories that moves through the sea ports of Sri Lanka. Accordingly, the variation of the percentage of sea cargo and air cargo exports in value is analysed. After identifying the major destinations for sea cargo exports, their behaviour in terms of demand for a certain time period is studied. Next, the categories are studied considering their contribution to the entire exports. The data (Secondary data) required in this analysis are, category and marketwise data for sea cargo and the total sea and air cargo export revenue of Sri Lanka. These data are collected from the Sri Lanka Export Development Board (EDB).

The second objective is to identify the factors that have the potential of affecting the export revenue of Sri Lanka. These factors were identified through the literature study. Accordingly, the identified factors are, national GDP per capita, World GDP, nominal exchange rate, FDI (Foreign Direct Investment) and trade agreements. Secondary data related to FDI, per capita current price GDP of Sri Lanka and other countries are collected from the word bank database. The nominal exchange rates of USD to Sri Lankan rupee are obtained from the database of Central Bank of Sri Lanka.

The final and most important objective is to formulate the final model. The technique used for modelling is econometric analysis. In the econometric model, sea cargo export revenue is used as the dependent variable and the independent variables are the factors that were identified when accomplishing the second objective. All the variables except trade agreements are qualitative variables and therefore, can directly be inserted to the model. But, trade agreements variable is considered as a dummy variable and assigned with the values 0 and 1 depending on the years of commencement and withdrawal of agreements. The contribution of Sri Lankan exports to the world exports is very low and therefore, it will not be fair to use the world per capita GDP in the model. Considering the revenue generated by major destinations, the countries which collectively contribute 63% of total exports are considered. Those countries are, USA, UK, India, Italy and Germany. The current GDP per capita of these countries are used to get a weighted average GDP and that is used in the model development.

Several linear models are developed using different combinations of the independent variables. The independent variable combinations are selected depending on the strength of their correlation coefficients. The best model that explains the sea cargo exports of Sri Lanka is selected by evaluating these linear models. The models are checked for the coefficient acceptability. The models with acceptable parameters are checked for the summary statistics such as coefficient of determination, standard error, ANOVA table and diagnostic tests. For all the analysis and model development purposes secondary data of 25 years, from 1990 to 2014 are collected.

3. Results of the Study

When analysing the export data, it was found that 80% of Sri Lankan exports by revenue are moved through the maritime leg. Until the introduction of air transport in Sri Lankan export sector in 1995, the entire cargo volumes have been moved through sea. The major destinations for Sri Lankan sea cargo exports are, USA, UK, India, Italy and Germany. Since 1990, USA is the best player capturing around 22% of Sri Lankan sea exports by value. United Kingdom, in 1990 stayed in the 3rd position and captured 2nd place from 1994 to 2015. India had absorbed the least percentage out of the five major players until 2000, and updated to the 4th position in 2001. But, India has jumped to the 3rd place from 2002 to 2009, with a sudden increase in Sri Lankan sea cargo exports by value. With a slight decrease in 2009, India regained its position in 2010, and again moved back to 4th place in 2011. From 2012 up to date, India is again the third best destination for Sri Lankan exports via sea. Until 1993, Germany is the second best player, but when it comes to the recent few years, Germany shows the lowest percentage out of the five major players. Italy had been the fourth best player in 1990 to 2000 and from there onwards its position is degraded to 5th. But again in 2005, it has shown an increase in its position surpassing Germany until 2015.

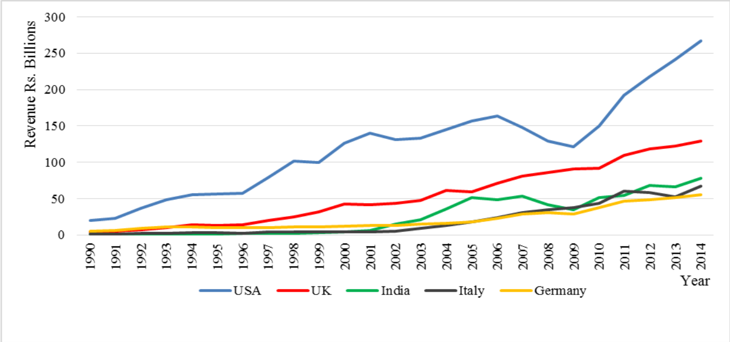

Figure 1: Export Revenue (Rs billion) for Major Destinations

The major product categories are, apparel, coconut products, gems, diamonds, petroleum products, rubber products, sea food and fish and tea. Apparel is the most outstanding sea cargo export of Sri Lanka and it has absorbed a considerable percentage over 34% in every year since 1990. It has even exceeded 50% in certain years. Out of 25 sub categories of coconut products, highest revenue is given by desiccated coconut and activated carbon. The contribution of coconut sea exports to total sea exports varies around 4%. Jewellery exports are the most outstanding among the category gems and diamonds. However, they have a very little contribution to the sea cargo exports and before 1995, almost all the revenue is generated through sea exports. Percentage of sea petroleum products out of total sea cargo exports varies in between 1% to 6% except for two cases where it is closer to 7% in 2010 and reduced even below 1% in 2013. It shows that 2013 has been the worst year for the petroleum product exports in Sri Lanka. In most of the years over the past 25 years, highest sea exports revenue is shown by bulk tea. Out of the total sea cargo, tea has captured around 16% and this is the highest share after apparel. Therefore, tea exports play a very important role in the export sector as well as in the maritime sector of Sri Lanka. Until 1996, the highest revenue in rubber exports is given by sheet rubber and from there onwards crepe rubber has become the outstanding revenue generator. Almost all the types of rubber products are exported through the maritime leg and this was the only major cargo type that has entirely been captured by sea transport, leaving a negligible percentage for air transport. Out of the total sea cargo, the rubber export percentage varies in between 0-4%. Until 2007, best sea freight revenue is given by prawns and in 2008 and 2009, frozen fish has obtained that place. From 2010 to 2013, other edible fish nes showed the highest revenue and again in 2014 prawns regained its place. Sea food and fish exports show an increasing shift to the air transport, because of its perishable nature.

All the five factors identified as independent variables hold a positive relationship with the sea cargo exports of Sri Lanka. The Pearson correlation coefficients of the factors with sea cargo exports are significant at 0.05 level. The strongest relationship is shown by national GDP and exchange rate. FDI, weighted world GDP and trade agreements show correlations in the decreasing order of strength. With the statistical evaluation of the developed models, it was found that the model which explains the sea cargo exports in the most successful manner consists of national GDP and exchange rate as the independent variables. The finalized econometric model is as follows.

SCER = -191 + 0.255 (NGDP) + 3.45 (ER)
Where,

- SCER: Sea Cargo Export Revenue (Rs billions)
- NGDP: National GDP Per Capita (current USD)
- ER: Nominal Exchange Rate (USD)

Figure 2 is the plot of actual sea cargo export revenue variation and the output values of the above model since 1990. This model explains sea cargo export revenue of 24 years and it does not explain the year 2009, which was found to be very special even in the data analysis. The reason for that is the global recession which was experienced by most of the countries and it is considered as the worst recession since World War II (International Monetary Fund, 2009).

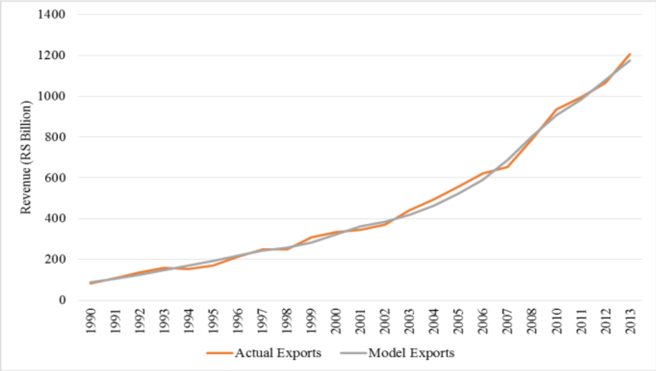

Figure 1 : Actual & Model Export Results

4. Conclusion

The analysis of the behaviour of the sea cargo exports and the selected factors is useful for the key stakeholders such as policy makers, freight forwarders, investors, shipping lines, government bodies such as ports authority and customs, and for academics. They can make use of the information and the formulated model in order to make their future strategic decisions and to utilize the market opportunities in the best way.

5. References

Adil Khan Miankhel, S. M. T. K. K., 2009. Foreign Direct Investment, Exports, and Economic Growth in Selected Emerging Countries: Multivariate VAR Analysis. p. 23.

Athar Iqbal, I. H. K. D., 2012. Relationship between Exports andEconomic Growth of Pakistan.

Bhatt, P. R., 2013. Causal Relationship between Exports, FDI and Income: The case of Vietnam. p. 16.

Carmen Sandu, N. G., 2011. The RElationship between Exchange Rate and Exports in Romania Using a Vector AutoRegressive Model. p. 7.

D.H. Kim, S. L., 2009. Trade and Growth at Different Stages of Economic Development. p. 12.

Dharmawardene, P., 2014. Trade Agreements-A Winning Strategy for Growing Sri Lanka's Exports. p. 13.

Dielman, T. E., 2005. *Applied Regression Analysis.* s.l.:South-Western Cengage Learning .

Export Development Board Sri Lanka, 2015. *Performanceof the Export Sector of Sri Lanka 2014*, s.l.: s.n.

Export Entreprises SA, 2015. *Foreign Investment.* [Online]
Available at: https://en.santandertrade.com/establish-overseas/sri-lanka/investing-3

Hettiarachchi, I., 2015. Reality Check of Sri Lanka's FDI and Emerging Role of Financial Investors. *Mirror Business*, 07 May.

International Monetary Fund, 2009. *World Economic Outlook-Crisis and Recovery* , s.l.: International Monetary Fund.

Kalaitzi, A., 2013. Exports and Economic Growth in the United Arab Emirates.

Kazunobu Hayakawa, F. K., 2008. The Effect of Exchange Rate Volatility on International Trade: The Implication for Production Networks in East Asia. p. 28.

Marinescu, N., 2007. The Link between Exports and Inward Foreign Direct Investment: The Case of Romania. p. 17.

Mohamed A. Elshehawy, H. S. R. A. A., 2014. The Factors Affecting Egypt's Exports: Evidence from the Gravity Model Analysis. p. 12.

Mohsen Mehrara, B. A. F., 2011. Granger Causality Relationship between Export Growth and GDP Growth in Developing Countries: Panel Cointegration Approach. p. 9.

Moses Joseph Shawa, Y. S., 2013. Causality Relationship between Foreign Direct Investment, GDP Growth and Export for Tanzania. p. 7.

Sanderatne, D. N., 2011. *Rapid increase in FDI flows in recent years.* [Online]
Available at: http://www.sundaytimes.lk/140525/business-times/rapid-increase-in-fdi-flows-in-recent-years-2-99899.html

Sapienza, E., 2009. The interaction between Export and FDI:Central-Eastern Europe and EU15. p. 32.

U. S. Department of Commerce, 2014. *The Role of Exports in the United States Economy,* s.l.: s.n.

WenShwo Fang, S. M. M., 2004. Exchange rate depreciation and exports:The case of Singapore revisited. p. 12.

Zakaria, Z., 2013. The Relationship between Export and Exchange Rate Volatility: Empirical Evidence Based on the Trade between Malaysia and Its Major Trading Partners. *Journal of Emerging Issues in Economics, Finance and Banking,* p. 17.

11:00 – 12:30 **Session 3A (Floor 17)** **Chair: Jin Chun**

Theme: Logistics (Cross-dock scheduling, Urban consolidation and Warehousing)

Urban Consolidation Centre for Improving Shopping Mall Logistics in Singapore
Giulia Pedrielli, Laura Gunarso, Ek Peng Chew and Loo Hay Lee

Data Driven based Clustering and Routing for Third-party Logistics
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Sharing Storage Spaces in Warehouses Owned by Independent Profit Makers
Kap Hwan Kim, Kang Tae Park, Xiao Ruan, Xuehao Feng and Xuefeng Jin

Urban Consolidation Centre for Improving Shopping Mall Logistics in Singapore

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6th International Conference on Logistics and Maritime Systems (Sydney, 21-23 June, 2016)

1. Introduction and Motivation

Shopping malls delivery plays an increasingly relevant role in today's urbanised society. Its impact is even more pronounced in Singapore due to its high density of shopping malls. Therefore, improving shopping malls delivery in Singapore has become an important topic in both societal and business/retail levels. At societal level, improvement in shopping malls delivery is necessary to reduce congestion, pollution, and safety problems. At business/retail level, improvement in shopping malls delivery is essential to help retailers meet their increasingly demanding customers' orders (Roca-Riu and Estrada, 2012). On the other end, it is compelling to improve the sustainability of such delivery process by reducing emissions increasing the utilization of trucks (Alexander, Floh, and Teller, 2015), in order to improve the mall logistics, improvement is required at the shopping mall delivery process level.

One possible strategy to achieve an improvement in such a process is the introduction of Urban Consolidation Centres (UCC), temporary storage places, often located at the outskirt of urban areas. With the use of UCC, manufacturers can then choose to deliver their goods to the consolidation centre instead direct mall delivery. The UCC operators will consolidate goods from multiple manufacturers hopefully reducing the number of deliveries. In fact, this model hopes to reduce the number of trucks entering the urban areas as it allows for sharing of delivery trucks among multiple manufacturers.

This work aims to provide insights on impact and feasibility of applying UCC on shopping malls delivery processes in Singapore by using simulation to assess different scenarios. Specifically, this paper aims to first analyse the current shopping malls delivery processes, which involves manufacturers, logistics providers, mall operators, and retailers, and model them into a simulation model. Subsequently, a simulation model on the UCC-delivery system is developed and the results of the two models were compared to assess the impact of UCC.

2. Literature Review

The use of UCC has gained attention in shopping malls delivery. UCC facilitates the pooling of delivery services, thereby minimising the number of delivery trucks used, time spent on the road, total distance travelled, and ultimately congestion and pollution. Moreover, UCC may allow bigger truck vehicles to move more freely as they do not have to enter the high-density city areas. Transport operators can also operate more flexibly not bound by retailers (Roca-Riu and Estrada, 2012).

Given its potential, UCC has become a centre of attention and one research focus has been its impact on various cost of operations. For example, Roca-Riu and Estrada (2012) analyses the impact of UCC on the unit cost of distribution by incorporating distance travelled and vehicle-hour in their mathematical model. Moreover, the paper shows the unit cost based on two scenarios, with and without UCC, and found that the use of UCC can significantly decrease the unit cost of distribution.

Teo and Goh (2011) proposes a statistical model to assess the impact of consolidating several centres into one bigger centre on inventory cost (2001). The mathematical model assumes that end-customer are indifferent of where the products come and that the outbound transportation cost will not change significantly due to transportation cost. The authors found that consolidation strategy does not always lead to a reduction in the total costs and that the effectiveness of the consolidation depends on the

demand distribution characteristics. However, instead of looking at UCC from a retail's point-of-view, this paper looks at UCC as a regional hub serving several countries, i.e., a much more aggregate perspective.
Looking at the diverging result of the researches, it can be argued that UCC may have the potential to be advantageous depending on the environmental circumstances in which it is applied. Hence, a simulation model is useful to complement the mathematical models in assessing the impact of UCC in Singapore's context. In this regard, existing research papers have provided various assessment models to evaluate the effectiveness of these logistics solutions. Specific to the shopping mall logistics in Singapore, a recent research on logistics process on malls in city area highlights that the Key Performance Indicators in the process can be bucketed into three main categories, namely *operational efficiency* (e.g. average turnaround time), *safety* (e.g. severity of congestion), and *environmental externalities* (e.g. noise and pollutants emitted by idle trucks). In the literature, various indicators have been proposed to assess the effectiveness of logistics solutions for urban distribution, which may be useful in building a more comprehensive and accurate simulation model to represent the shopping malls delivery in Singapore. In fact, to the knowledge of the authors, no research projects attempt to simulate the retail logistics in the Singapore scene. This paper proposes a UCC architecture and a simulation model presenting the first preliminary results to assess the advantages of such logistics solution.

3. Methodology

We use simulation as the technique to evaluate the advantages of the Urban Consolidation Centre with respect to the current logistics system running in Singapore. We will refer to the simulation model representing the current situation as *Baseline Design*, whereas the proposed configuration will be referred to as *UCC Design*.
The simulation models were coded in C# language extending the O^2DES simulation platform in Li et al. (2015). Simulations are terminating with length of one day (8 hours by default, but changeable). For now, the proposed KPIs are *operating efficiency* of mall operators, indicated by *number of trucks*, average *waiting time*, and average *service time*. The service time itself covers both *unload time* and *in-mall delivery* (IMD) *time*. These metrics are stored as attributes of class *mall*, i.e. they characterize each shopping mall in the current and new model. At the end of a simulation experiment, a list of malls is returned with the related value of the attributes resulting from the simulation. Hence, we use the results to compare the different strategies.
The simulation considers a network of shopping malls, giving the possibility to define a different demand and service distributions reflecting different sizes and mix of tenants, as well as different traffic rate due to the different location location. Each mall is further characterized with the number of loading bays, and traffic rate. The model further assumes that malls are independent in the demand generation i.e., tenants in different malls generate independent demand.

3.1 Baseline design

According to the O^2DES platform in Li et al. (2015), the baseline design consists of 5 components, each characterized by different functions.

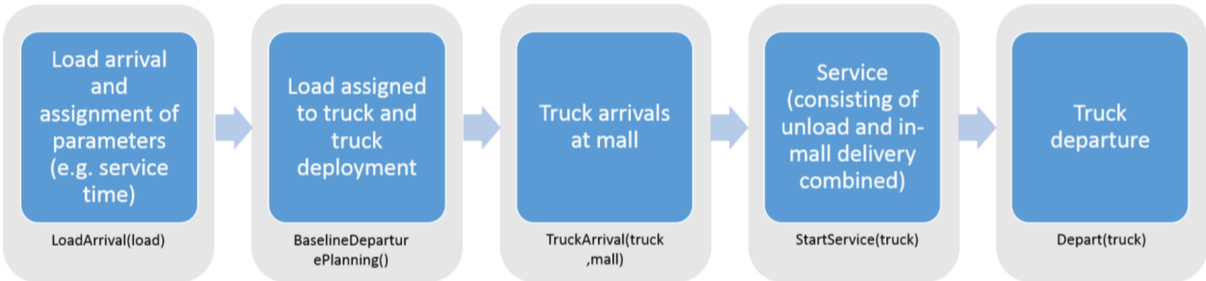

Figure 1: Baseline Design Simulation Model Components

Specifically, in *LoadArrival*, each load (retailer/tenant demand) in the model represents one request order from one tenant. Hence, each load has attributes of volume, delivery truck it will be transported by, and its destination mall. Moreover, each load will also be immediately assigned a service time based on the service rate of the mall from which the order come. In the current implementation, we assume that the service rate of each mall does not change throughout the simulation run and it follows an exponential distribution. In other words, this function reproduces the process when retailers/tenants place orders to manufacturers and manufacturers prepare the necessary goods to be delivered.
In *BaselineDeparturePlanning*, each load is assigned to one truck. We assume that one truck will be deployed for each load that arrives. This represents the scenario when manufacturers use their own trucks to deliver orders to their tenants instead of consolidating orders from multiple tenants. The truck will be assigned traffic time based on the traffic rate of the mall from which the order come. The traffic time is then used to schedule the truck arrival at the mall.
The *TruckArrival* represents the arrival of a truck at a shopping mall. The truck will check for any empty loading bays and start unloading if it can find one. Otherwise, it will join the waiting line.
StartService represents unloading and in-mall delivery processes, combining both to give one service time. Since each load has its own service time generated in the load-generation phase, the total service time for the truck in the mall will be the sum of all the service time of the loads meant for that mall. As such, departure of truck is scheduled as the time it starts service plus the total service times.
Depart represents the step where truck has finished its delivery process at one mall and depart the mall. It will then check again if it still has loads to be delivered to other mall. If there are, the model will get the destination of the first next load and schedule truck's arrival at the next mall. Otherwise, the truck will be removed from the model. As for the mall itself, departure will trigger the model to check if there are any trucks waiting to unload. If there are, the model will move the next truck into freed loading bay to start service. If there are not, the loading bay will be set free.

3.2 UCC design

The UCC design shares most of the components with the baseline design, with the exception of departure planning. In fact, the UCC design incorporates the possibility of consolidating orders before sending the goods altogether, and this is obtained by adding the method *UCCDeparturePlanning* (Figure 2).

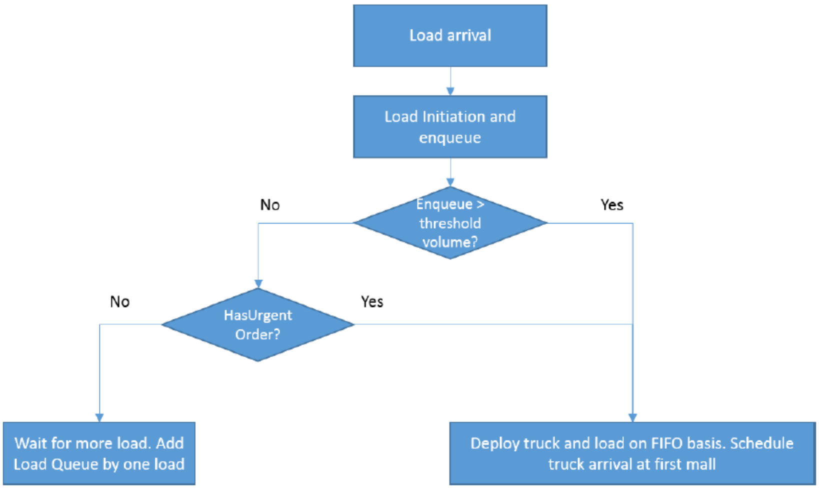

Figure 2: UCCDeparturePlanning flow chart

Specifically, similar to the baseline design, each load represents one request order from one tenant. The difference is that this step requires the model to check all the load in the queue to see if there is any urgent order, which is defined as load whose order deadline is less than the expected traffic time from now. If yes, a truck will be deployed. If there is no urgent order, the model will continue adding loads to one truck on FIFO basis and deploy truck only when the loads accumulate to certain volume. For now, the volume is assumed to be the full capacity of the delivery truck.

4. Preliminary Results and Remarks

The preliminary results were obtained simulating 3 malls which we will refer to as *Small*, *Base*, and *Big*. The *Base* mall parameters are derived from a field observation on one shopping mall in Singapore provided with 16 loading bays, 31.2 demand rate (load/hrs), and 1.62 service rate (load/hrs). *Small* is the mall assumed to have 0.75 times the number of loading bays and demand rate as it serves fewer tenants, as well as the service rate 1.25 times the base due to faster IMD time. *Big* is assumed to have 1.25 times the number of loading bays and demand rate as it serves more number of tenants, as well as 0.75 times the service rate as the bigger mall may take longer IMD time.

At this stage, the simulation model runs for 8 hours to represent the period observed in the primary observation and does not consider traffic factors. Both the Baseline and the UCC solution are provided the same sample path in terms of demand.

Table 1: Preliminary Results of Baseline and UCC Designs

	Small	*Base*	*Big*	Average
Baseline Design				
Number of trucks (veh/day)	186.40	182.80	186.00	185.07
Waiting time (mins/veh)	8.58	31.12	61.16	33.62
Service time (mins/veh)	24.88	37.02	44.23	35.38
UCC Design				
Number of trucks (veh/day)	170.60	179.40	176.40	175.47
Waiting time (mins/veh)	1.43	20.03	50.41	23.96
Service time (mins/veh)	24.65	35.44	45.45	35.18

Table 1 shows the average operational efficiency in terms of the *number of trucks*, *waiting time*, and *service time* across multiple simulation replications. We observe how the average number of trucks, waiting time, and service time of the three malls combined decrease with the proposed UCC model. This means, given the same volume during the simulated time, that the UCC model requires fewer number of trucks and shorter operational times. This is a promising result for the UCC model.

However, comparison on each mall shows that the direction and the extent of the changes differ from one mall to another. In terms of percentage change, the number of trucks decreases the most (8.48%) for *Small* and the least for *Base*. Waiting time also decreases the most for *Small* and the least for *Big*. Meanwhile, service time decreases the most for *Base*, stays approximately the same for *Small*, and increases instead for *Big*.

One possible reason is that the range of demand and service rates may have a different effect on the changes as different malls have different demand and service rate. Nevertheless, the assumption that the service time is not affected by the load's volume may also have a large impact over the results.

Following the preliminary results, a more detailed experiment will be developed by relaxing the assumptions in section 3. This also includes analysing the effect of load's volume as stated above as well as other factors such as traffic rate and truck capacity.

References

Alexander, A., Floh, A. & Teller, C. (2015). The Impact of Competition and Cooperation on the Performance of a Retail Agglomeration and its Stores. Industrial Marketing Management.

Teo, C. P., Ou, J., & Goh, M. (2001). Impact on inventory costs with consolidation of distribution centers. IIE Transactions (Institute of Industrial Engineers), 33(2), 99-110.

Roca-Riu, M. & Estrada, M. (2012). An Evaluation of Urban Consolidation Centres through Logistics Systems Analysis in Circumstances where Companies have Equal Market Shares. Seventh International Conference on City Logistics, 39, 796-806.

Li, H., Zhu, Y., Chen, Y., Pujowidianto, N., and Pedrielli, G. (2015, December). The C# Paradigm for Discrete Event Simulation Modeling: a Case Study on Aircraft Spare Part Management. In Proceedings of the 47th Winter Simulation Conference.

Data Driven based Clustering and Routing for Third-party Logistics

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6th International Conference on Logistics and Maritime Systems (Sydney, 21-23 June, 2016)

1. Introduction

With the explosive increase of e-commerce in Singapore, it has become a great challenge for the third-party logistics (3PL) to maintain/improve customer satisfaction and operation efficiency. One of the world's leading logistics company in Singapore (the company) is now dealing with high volume of deliveries and varying pickups as shown in Figure 1. Every day, a company can receive up to 10,000 parcels. Usually van fleet departs from the around 8 a.m., and amongst all parcels, the majority of them have to be delivered before 10 a.m. or before 12 p.m., whilst pickups are ad-hoc from varying locations. Most of the times, in the real practice, parcels are manually assigned to each vehicle and the vehicle routing is determined by the drivers. The inefficiency derived from such an approach can lead to decreasing service level due to the delivery delays, workload imbalances between vehicles, etc. Therefore, it is important to have an efficient and effective method to deal with pick-up and delivery.

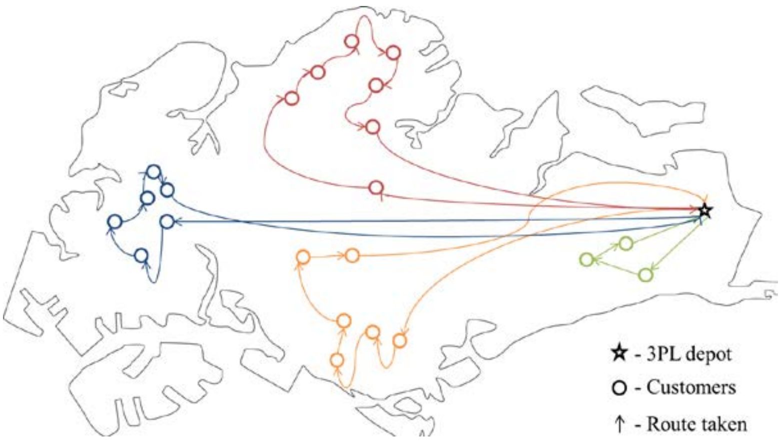

Figure 1: Business mode of a 3PL in Singapore

In fact, the pickup-delivery problem with time window extends the vehicle routing problem. As a NP-hard problem, exact algorithms are commonly used but only be able to solve with around 100 customers (Baldacci et. al., 2012), albeit at a high computational time. Unfortunately, this number of customers is not practical in the real world. Therefore, we propose a heuristic to provide good solutions within acceptable computational time.

In this area, Ozdamar & Demir (2012) proposed a cluster-first-route-second heuristic that divides demand clusters using the k-means partitioning heuristic. Specifically, K demand nodes are randomly selected as cluster centroids, and the remaining nodes are assigned to the nearest centroid, recalculating cluster centroids iteratively. Another cluster-first approach by Mitra (2008), differs from Ozdamar (2012), such that cluster centroids are not randomly selected. The cluster centroids are identified based on distance. In particular, the customer located furthest from the depot will be in the first cluster. Subsequent clusters are assigned based on the furthest sum of distances from already allocated clusters.

Currently, the company allows their drivers to decide their route because the drivers know the road infrastructure, including the daily traffic conditions. In light of this, this study adds to the current state of the art as it incorporates the historical delivery data and the online traffic data, i.e. Google Maps, to determine the clustering and routing, and eventually proposes an innovative heuristic algorithm. The objective is to develop a route for each vehicle to fulfill all customer demands, within the given constraints, while keeping costs minimal. The cost in the context of this paper is defined as the number of vehicles used, and the total makespan of all the vehicles.

The remainder of the paper is structured as follows: Section 2 will explain how the algorithm is designed and Section 3 shares the preliminary result and the roadmap of this study.

2. Methodology

An overview of the methodology used in this study is shown in Figure 2.

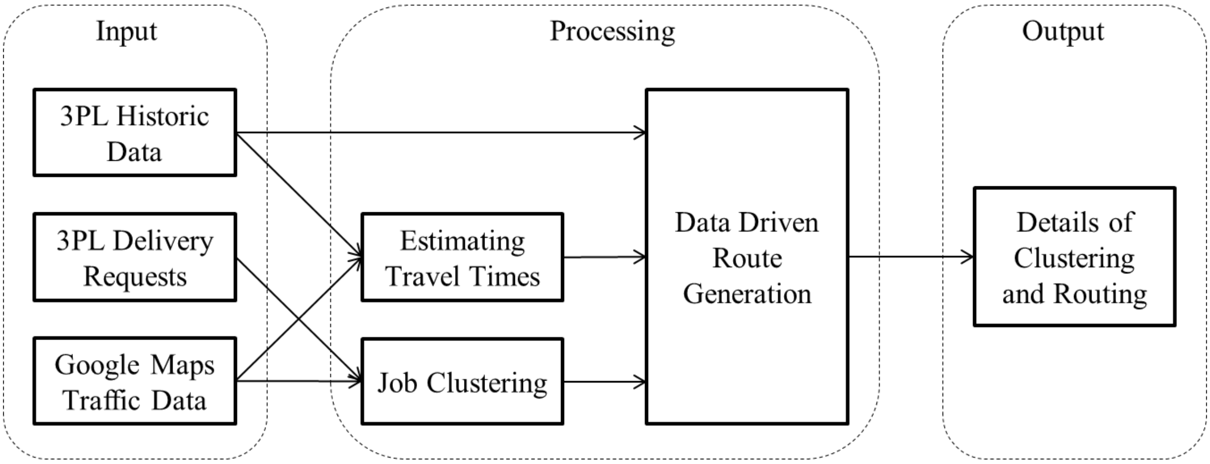

Figure 2: An overview of the methodology

2.1 Input Data

In this study, the historical delivery data and the online traffic data are used to determine the clustering and routing. The historical delivery data collected from the company's couriers were utilized in two ways. First, frequently traveled road segments are prioritized over routes produced the proposed heuristic as this information reflects the actual situation 'on the ground'. Some examples of these include traffic conditions, and one-way streets. The second way is to estimate the delivery durations from origin to destination, and from vehicle to customer. The online traffic data is based on Google Maps. To be specific, coordinates are necessary to transform daily delivery information (postal code format) into visual representations. These coordinates will also assist in estimating the travel durations between two locations on a map. Geographic longitude and latitude coordinates were retrieved from Google Maps (stored offline) and are used as substitutes for the X and Y coordinates on a two-dimensional map.

Eventually, the clustering and routing decision is made for the 3PL delivery requests, which contains the delivery information, such as the number of deliveries, their postal codes, and their respective cut-off times.

2.2 Estimating Travel Times

An important component required to solve any VRP is the quantification of cost incurred when a route is taken. Commonly, the cost is a function of the distance between origin and destination. However, the company is more interested in customer satisfaction (which relates to time); therefore, we chose time instead of distance as main performance measure. In order to compute such a function, we developed a model is to estimate the time required to travel between two points, using their geographic coordinates, as well as 3PL historic data. In particular, using geographic coordinates, the distance between two points can be estimated by considering the Manhattan distance, and Euclidean distance.

2.3 Job Clustering

Currently postal codes are allocated to specific vans, meaning that each van will always deliver to the same postal code. The number of van used inflates because vans with few deliveries are also dispatched. The proposed dynamic clustering algorithm is as follows:

Step 1) K = total deliveries / constant

Step 2) Get K initial centroids

Step 3) Repeat until the terminate condition is met:
  a) Evenly distribute deliveries to clusters, update the location of the centroids
  b) Allocate deliveries to clusters based on distance, update the location of the centroids

Step 4) Repeat until the terminate condition is met:
  Allocate deliveries to clusters based on distance, incrementally update centroids.

Specifically, Step 1 defines the number of clusters, by specifying a constant that denotes the desired sized of the cluster. Step 2 generates the initial *K* centroids. Instead of randomly generating the initial centroids, we sequentially generate them by starting from the point which is geographically most far away from the company depot (i.e., the origin of the trucks). Subsequently, the centroids are generated to maximize the distance from the existing ones. This guarantees an initial solutions with spread out centroids. As a result, of this initialization we tend to have fewer iterations in steps 3 and 4. Step 3 serves as an initial calibrator. Step 3a imposes a condition that each cluster must have the same number of deliveries, to 'pull' the centroids towards densely populated areas. Step 3b, subsequently, relaxes this condition, allowing the centroids to spread out. Once all the points have been reassigned, centroids are recalculated. Step 4 serves as the final calibration. It is the same as step 3b, except that instead of recalculating the centroids only once all the assignments have been performed, it incrementally recalculates the centroids after each individual point has been allocated. The termination condition for both steps 3 and 4 are either completing a set number of iterations, or when convergence is reached (i.e., the centroids do not change in subsequent iterations).

2.4. Data Driven Route Generation

We propose a greedy approach for routing. Estimated times, and 3PL historic data will be utilized here. For example, there are three deliveries: X, Y, Z, with estimated times X→Y: 10 min, X→Z: 8 min. The routing algorithm will greedily choose X→Z. However, if couriers always select X→Y instead of X→Z, priority should be given to X→Y as there may be situational complications. Therefore, a function to tradeoff between frequency of selection and shortest time is. In particular we use

$$\left(1-\frac{F}{O}\right)\times D$$

Where *O*, or *Occurrences*, is the number of times all 3 deliveries present; *F*, or *Frequency*, is the number of times X→Y is chosen during the occurrences; *D*, or *Duration,* is the travel time between X and Y.

3. Preliminary Results and Conclusions

Table 1 shows the comparison between the objective value (OV) of the proposed heuristic in Section 2.3 and the best solution computed from multiple replications of the standard k-means clustering approach. The results are as follows:

Table 1: Comparison between proposed clustering heuristic and standard k-means

Date (in Oct)	Proposed Heuristic OV	Standard k-means OV	Replications for standard k-means	Difference (in km)	Unique Postal Codes	Difference per postal code (in m)
19th (Mon)	2735	2660	503	75	2041	37
27th (Tue)	3722	3700	506	22	2743	8
21st (Wed)	3892	3862	505	30	2794	11
15th (Thu)	2890	2809	509	81	2122	38
16th (Fri)	3550	3460	513	90	2627	34
24th (Sat)	3564	3470	502	94	2587	36

As can be seen, the largest difference is on 15 Oct, with an average distance of 38m difference per point. Taking into account the time required to traverse 38m, which is a considerably short amount of time, the proposed heuristic can be considered as good.

This study is still in progress and is planned for 6 months since October, 2015. So far the ideas relating to the estimation of the time required to travel between destinations, and route sequencing have been formulated. We are currently testing the presented ideas over real data provided by the 3PL partner. Specifically, we are comparing the heuristic’s generated route and historic route sequences.

References

Baldacci, R., Mingozzi, A., & Roberti, R. (2012). Recent exact algorithms for solving the vehicle routing problem under capacity and time window constraints. *European Journal of Operational Research*, **218**(1), 1-6.

Özdamar, L., & Demir, O. (2012). A hierarchical clustering and routing procedure for large scale disaster relief logistics planning. *Transportation Research Part E: Logistics and Transportation Review*, **48**(3), 591-602.

Mitra, S. (2008). A parallel clustering technique for the vehicle routing problem with split deliveries and pickups. *Journal of the operational Research Society*, **59**(11), 1532-1546.

Sharing Storage Spaces in Warehouses Owned by Independent Profit Makers

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1. Introduction

This presentation discussed how to share storage space among independent profit-making owners of warehouses. For the operation of the proposed system, a method to resolve conflicts among participants is suggested. A mathematical model is suggested for analyzing the efficiency of the entire system. The mathematical model is converted into price adjusting sub-problems and warehouse selection sub-problems, which are appropriate for the distributed decision-making process. As a logical framework for the distributed decision-making process, sub-gradient optimization is proposed.

In most warehouse systems, information on the amount of empty space of each individual warehouse is not open to shippers. However, with the use of Internet applications, it can be just as easy to obtain information about available space of a warehouse remotely as it can obtain such information locally. Similarly, Internet applications can be developed which allow for efficient control of available space remotely and for organized access to available spaces that are geographically dispersed.

The physical location of warehouses would be geographically dispersed. In addition, warehouses might be owned by different companies or persons. Virtual warehouses, therefore, have the potential to effectively remove constraints on space and ownership, and they would be means by which the efficiency of warehousing could be greatly increased.

In conventional warehouse systems, an owner of a private warehouse stores exclusively only his/her products in his/her own warehouse and sends excessive storage demands to a public warehouse in case that the amount of available space of his/her own warehouse becomes to exhaust. Because the storage demand of a company fluctuates significantly, the utilization of privately owned warehouses may be low.

In the virtual warehousing systems, spaces located in different warehouses, which are owned by independent profit makers, are shared with each other. The information about them can be open through the Internet. For using a certain amount of space, owned by other participants, for a certain period of time, the user must pay a charge to the owners. In the decision-making, all shippers choose warehouses to stock their storage activities only in terms of costs. But, the reliability of warehouse and easiness of access to warehouse are not included in the cost. By sharing all the warehouses, the total operating cost is expected to decrease and the overall operation efficiency is expected to improve.

However, considering owners of warehouses are different from each other, various operational issues must be solved before the system can be implemented. For example, there must be a method to resolve conflicts among participants when the total space demand for a warehouse exceeds the total available space of that warehouse at that time. Also, it must be determined how to charge for a usage of a space by a participant who is not the owner of that warehouse. Most of all, the most important thing is that all the participants must have motivations to participate in the virtual warehousing system. It means that all the members in the system must be better off than when they do not participate in the

virtual warehousing system. The above issues are addressed in this presentation.
Clarke [2] described the virtual logistics widely, and suggested the applicable areas from the viewpoint of virtual logistics. And van Hoek [3] proposed that essential elements of virtually integrated business include the integration of the chain and the extensive degree of outsourcing and subcontracting.

The next section discusses how the concept of virtual warehouses can be implemented in practice. Section 3 proposes a method of allocating and pricing storage spaces for resolving conflicts among warehouses.

2 A business work flow for sharing storage spaces

A virtual warehousing system involves more than one manager of warehouses. Space allocation decisions are made via Internet among managers of warehouses as follows: As shown in Figure 1, managers of warehouses post information on their available space onto the virtual warehouse system via the Internet. The information of all warehouses is open and shared only to the managers in virtual warehousing system. When a manager receives a storage order from a shipper, the manager retrieves information on available spaces of warehouses from the virtual warehouse system. Considering the amount of the available space, the price of the space, and the transportation cost from the current location of the freight, to the warehouse, and from the warehouse to the destination of the freight, the manger selects a warehouse and constructs his/her bid which includes the period and the amount of the storage. The bid is sent to the selected warehouse.

The manager of each warehouse collects bids and commits the assignment for a certain storage order. For certain future time periods, the manager adjusts the price of the space. When there is no bid for a certain period, the price of the space for the period will be lowered. Also, when more than two bids are submitted for a certain period, the price of the space for the period will be increased. This procedure is repeated until every storage order is assigned to a warehouse. At the deadline of a commitment, the assignment is fixed.

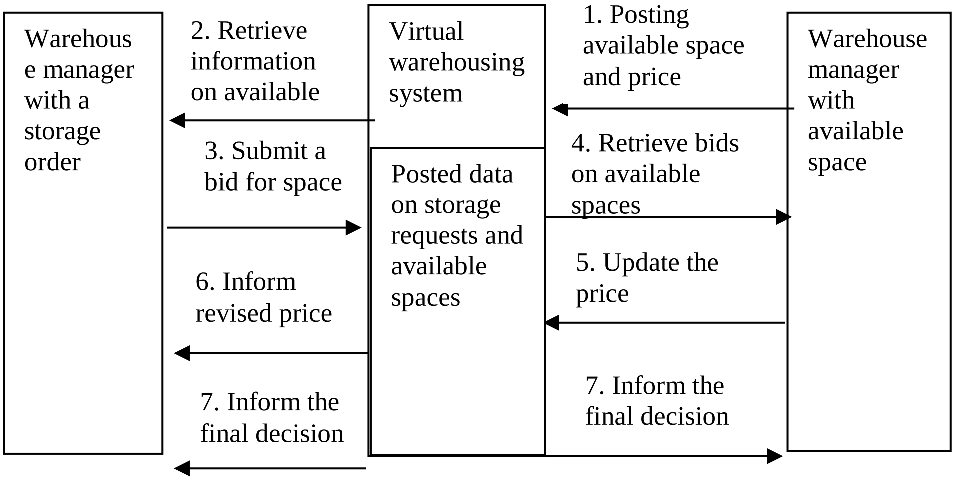

Figure 1. A business work flow for virtual warehouses

3 Pricing and scheduling storage activities

In the virtual warehousing system, orders to be processed are storage activities each of which has the time and the location of its generation and extinction. A storage activity (SA) is defined by an amount of inventory (space requirement), a pickup location of inventory, a storage starting time, a delivery location, and a storage finishing time.

The space allocation problem can be represented by a network as shown in Figure 2. There are three types of nodes in the network: a source node representing arrival at the warehouse, a terminal node representing departure from the warehouse, and intermediate node representing the storage at a warehouse. An intermediate node, l^i, represents the storage at warehouse *l* at time *i*. There are two types of arcs between intermediate nodes. One is the storage arc that connects a node, r^j, to another node, r^{j+1}, and represents storage of an SA at warehouse *r* from time *j* to time *j+1*. The storage arc is usually limited in its capacity that coincides with the storage capacity. The other is the relocation arc that connects an intermediate node, r^j, to another intermediate node, u^v, where $r \neq u$ and $v \geq j$, which represents a pickup of an SA from warehouse *r* at time *j*, transporting and delivering of the SA to warehouse *u* at time *v*. The cost of a relocation arc includes the loading cost of the SA onto a transportation facility at the pickup node, transportation cost from the pickup node to the delivery node, and the unloading cost at the delivery node.

Then, the space allocation problem can be interpreted as a problem determining routes that each SA should flow and amounts of the SA that should flow through each selected route. A route for an SA consists of a set of nodes including a source node, intermediate nodes, a terminal node, and arcs connecting these nodes. An example of a route is as follows:

$$R: s_i \rightarrow 1^3 \rightarrow 1^4 \rightarrow 1^5 \rightarrow 4^8 \rightarrow 4^9 \rightarrow t_i,$$

which can be interpreted as a route for an SA *i* of which source location is s_i and destination location is t_i. It is generated at time 3 and extinguished at time 9. According to this route, SA *i* is moved to storage location 1 from the source location, then stored at location 1 until time 5, relocated to storage location 4. The relocation takes 3 time units. The SA is stored at location 4 until time 9, and then sent to the destination location.

If only one SA is considered, the total-cost minimization problem is to select the least cost route from the source node to the terminal node. However, when multiple SAs are simultaneously considered, selecting the least cost route for every SA may not be allowed because of the limitations on the capacities of warehouses.

The space allocation problem is formulated by a mixed integer linear programming model and an heuristic solution procedure, called “sub-gradient optimization,” is proposed. In this presentation, it is attempted to utilize this process as a method to resolve conflicts among storage activities when the space demand for a warehouse is greater than the available space of that warehouse. Also, the value of Lagrangean multiplier, which can be obtained from the procedure of the sub-gradient optimization, is shown to be used as a real charge that the manager with storage activity *i* should pay to the owner of warehouse *k* for using a unit space during period *j*.

The gain in the total cost resulting from the collaboration among participants needs to be distributed to the participants and the distribution of the gain should be fair. This presentation will discuss how to distribute the gain to participants in a fair way.

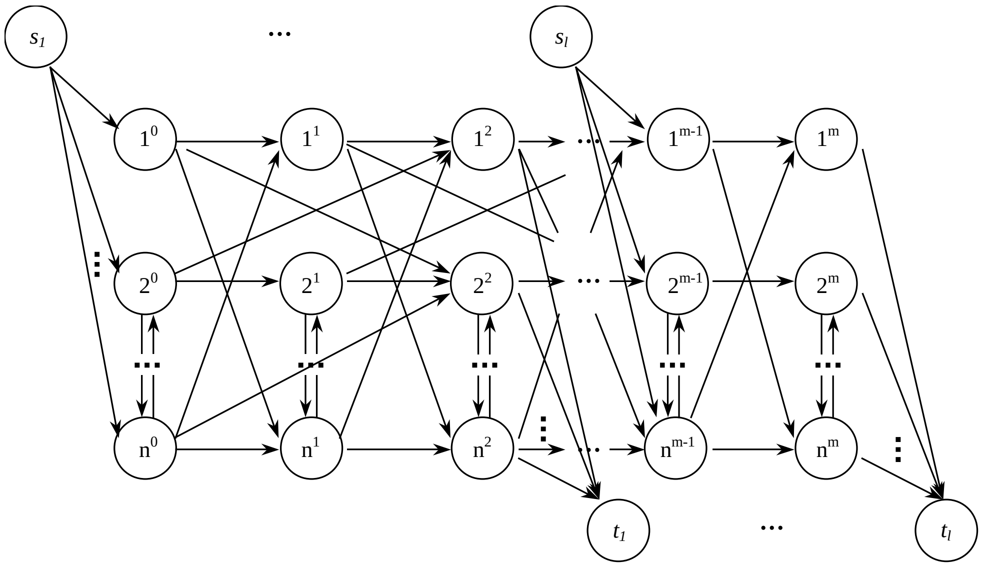

Figure 2. A network representation of the space allocation problem

4 Conclusions

Concepts of virtual logistics were applied to the management of storage space in warehouses. In storage space sharing systems, spaces in warehouses with different owners are shared with each other. For the operation of the proposed system, a method to compensate real owners of a storage space for using the space was devised. A mathematical model was suggested for analyzing the efficiency of the entire system. It was shown that the mathematical model could be converted into price adjusting sub-problems and warehouse selection sub-problems, which describe well real world trading of products in a distributed way. As a logical framework for the distributed decision-making process, sub-gradient optimization was proposed. As a future study, more numerical experiments are needed for validating the concepts in this presentation. Also, the concept of virtual logistics can be applied to other logistic resources by using a similar process suggested in this presentation.

References

1. M Held, P Wolfe, and H P Crowder (1974) Validation of sub-gradient optimization, *Math. Programming* 6, 62-88.
2. M P Clarke (1998) Virtual logistics, *International Journal of Physical Distribution & Logistics Management* 28(7), 486-507.
3. R I van Hoek (1998) Logistics and virtual integration, *International Journal of Physical Distribution & Logistics Management* 28(7), 508-523.

11:00 – 12:30	Session 3B (Floor 16) Theme: Maritime (Environment)	Chair: Rommert Dekker

Artificial Neural Network Model for Ship Fuel Consumption Prediction with Applications to the In-Service Ship Fuel Consumption Management
Yuquan Du and Qiang Meng

The Implications of Environmental Regulation on Sailing Speed Optimization
Thalis Zis, Panagiotis Angeloudis, Michael Bell and Harilaos Psaraftis

Tactical Bunker Management for Operational Flexibility and Risk Management in SECAs
Stein W. Wallace, Xin Wang and Yewen Gu

Artificial neural network model for ship fuel consumption prediction with applications to the in-service ship fuel consumption management

Yuquan Du[1], *Qiang Meng*[2*]

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1. Introduction

Liner container shipping plays a vital role in the maritime transportation. The ship fuel efficiency has recently become a big concern in the liner container shipping industry due to the environmental and commercial reasons. Basically, ship fuel efficiency can be improved through technological and managerial measures. ClassNK, a leading ship classification society, advocates the evolution from *eco-ships* to *eco-shipping* which highlights the roles of data analytics and managerial approaches in ship fuel efficiency management (Nakamura, 2015).

Voyage report data accumulated in the liner container shipping company are quite useful for the ship fuel efficiency analysis. When a commercial ship sails at sea, the captain is required to report the sailing profile to the on-shore offices on a regular, usually daily, basis. The sailing profile consists of many aspects of the ship's sailing behaviors, such as geographic locations, local and GMT times, distance covered since last report, speed, cargo and ballast water loaded, displacement (the total weight of ship itself, cargo, ballast water and bunker in terms of metric ton (MT)), trim (aft draft minus forward draft), weather and sea conditions (wind, waves, sea currents and sea water temperature), and fuel consumption by the main engine, auxiliary engines and boilers. At noon of every day, the captain conveys a data entry describing the recent sailing profile to on-shore officers. That is why voyage report data are also called *noon report* data by captains. Voyage report data are also called *shipping log* data since these data are stored in the logbook.

Voyage report data were adopted by few existing studies to model a ship's *fuel consumption rate* in terms of MT/day (also referred to as *fuel efficiency*). Pedersen and Larsen (2009) and Beşikçi et al. (2015) develop some artificial neural network (ANN) models to examine the influence of several determinants (speed, displacement, trim, weather/sea conditions, etc.) on a tanker's fuel efficiency. However, their domain knowledge on the fundamental principles of ship fuel efficiency is a little biased, which causes the inappropriate choice of input (explanatory) variables of their ANN models. Pedersen and Larsen (2009) unnecessarily define "time" as an explanatory variable, while Beşikçi et al. (2015) regard engine RPM (revolutions per minute) together with speed, draft (equivalent to displacement), trim, and weather/sea conditions as an explanatory variable of ship fuel efficiency, which actually confuses the impacts of the factors outside of the engine with that of engine performance. The inappropriate choice of input (explanatory) variables results the difficulty of applying an ANN model in ship fuel efficiency analysis and management. Second, the overfitting/generalization issue originating from data inadequacy is not recognized by the ANN models in Pedersen and Larsen (2009) and Beşikçi et al. (2015). Third, we do not find a practical scheme for ship fuel consumption management based on ANN models in Pedersen and Larsen (2009) and Beşikçi et al. (2015).

The contributions of this study to the existing studies are threefold: (a) by complying with the fundamental principles of ship fuel efficiency, we propose three ship fuel efficiency models, compare their performance based on the voyage report data of several containerships, and deliever some insights for ship fuel efficiency modeling; (b) the overfitting/generalization issue is overcome; (c) additionally, we propose a practical in-service bunker fuel consumption management scheme for a containership, based on the ANN model's capability of predicting the daily fuel consumption of a ship.

2. Artificial neural network models for ship fuel efficiency

According to the fundamental principles for ship propulsion, the fuel efficiency of a ship can be predicted by a two-step procedure shown in Fig. 1. The first step predicts the engine resolution speed requirement (RPM) using desired sailing speed, displacement, trim, and weather/sea conditions, which represent the ship's performance outside the (main) engine, while the second step projects the engine RPM to the fuel consumption rate based on the influence of RPM on power needed (kW) and on specific fuel oil consumption (SFOC, g/kW-hr), which actually quantifies the engine performance. It can be seen from the second step that multiplying the power needed and SFOC produces the fuel consumption rate. Based on existing studies on ship fuel efficiency, in the first step, we have to take advantage of a black-box model, e.g. ANN model, to reflect the extremely complicated synergetic influence of the determinants outside the engine (speed, displacement, trim and weather/sea conditions). In the second step, the prediction from engine PRM to fuel consumption rate can be fulfiled via either a black-box model or a while-box model (nonlinear regression).

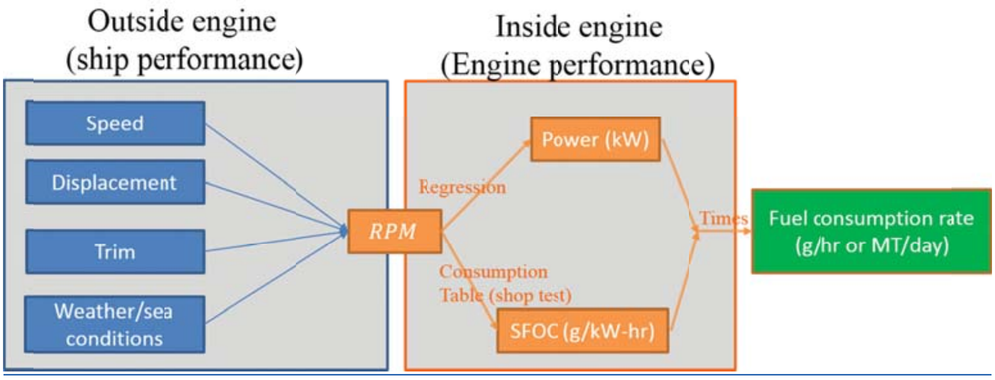

Figure 1: A two-step procedure for ship fuel efficiency prediction

Three possible models relying on voyage report data are proposed. Model 1 adopts an ANN model in the first step and a nonlinear regression model in the second step. Model 2 retrofits Model 1 by using another ANN model for predicting fuel consumption rate against engine RPM in the second step. Model 3 simply combines the two ANN models for the two steps into one ANN model, shown in Fig. 2. Experiments based on two 9000-TEU containerships compare the fitting performance of Models 1 to 3. It is also worth noting that we using some techniques to address the overfitting/generalization issue caused by data inaccuracy, which is not noticed by Pedersen and Larsen (2009) and Beşikçi et al. (2015).

3. A practical in-service fuel consumption management scheme for liner containerships

Based on the ANN models' capability of precisely predicting fuel consumption rate of a ship, we innovatively propose a practical fuel consumption management scheme for the in-service liner containerships, which is illustrated by Fig. 3. As shown in Fig. 3, the containership under consideration sails on the current trip labelled by ADO21, and it just completed its voyage from Yokohoma to Ningbo. Its next voyage will be from Ningbo to Kaohsiung. The first component of this proposed scheme aims to monitor and analyze its fuel efficiency for the completed sailing part of the trip from Singapore to Ningbo. A $2\text{-}\sigma$ or $3\text{-}\sigma$ control limit, based on the historical FEIs (fuel efficiency index) in this part, is designed to monitor the possible abnormalities of fuel efficiency of the ship. Once an abnormality, namely the current FEI out of the control limit, is detected, our ANN model will be employed to break down the impacts of speed, displacement, trim and weather/sea conditions on ship fuel efficiency, and to find the reasons for this abnormality. The second component is a request-inspection mechanism between the captain and on-shore fuel specialists for the upcoming voyage: before the start of the voyage from Ningbo to Kaohsiung, the captain ask the on-shore fuel specialists for a certain amount of bunker fuel, while the on-shore fuel specialists inspect the rationality of the bunker fuel amount by predicting the ship's fuel consumption based on speed, displacement, trim and weather/sea conditions in this voyage. Components 1 and 2 in Fig. 3 together constitute the proposed bunker fuel consumption management scheme. An example will be used to shown the applicability of this scheme.

4. Conclusions

This paper develops three voyage report data driven ship fuel efficiency models, and compares their fit performance over two 9000-TEU containerships. Based on the ANN models' capability of predicting fuel consumption rate, we propose a practical in-service fuel consumption management scheme for a containership consisting of a fuel efficiency analysis component for the completed part of the trip under consideration and a request-inspection mechanism for the upcoming sailing voyage.

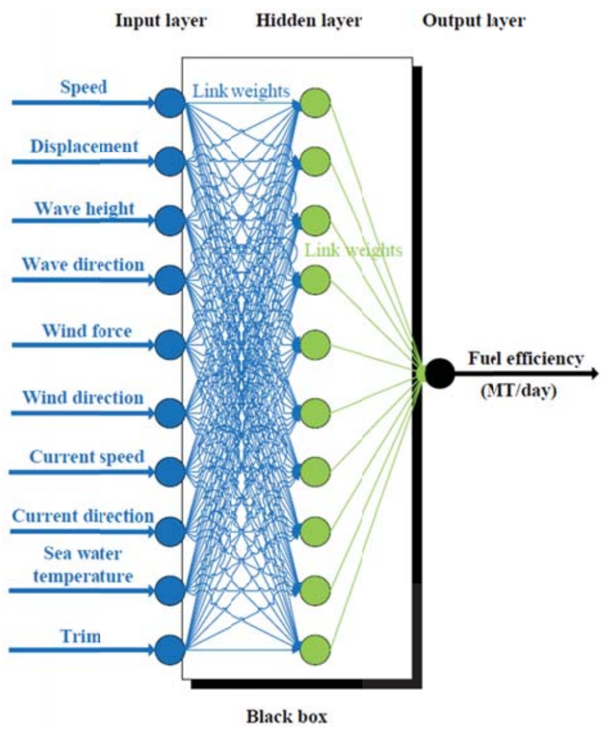

Figure 2: An ANN model for ship fuel efficiency

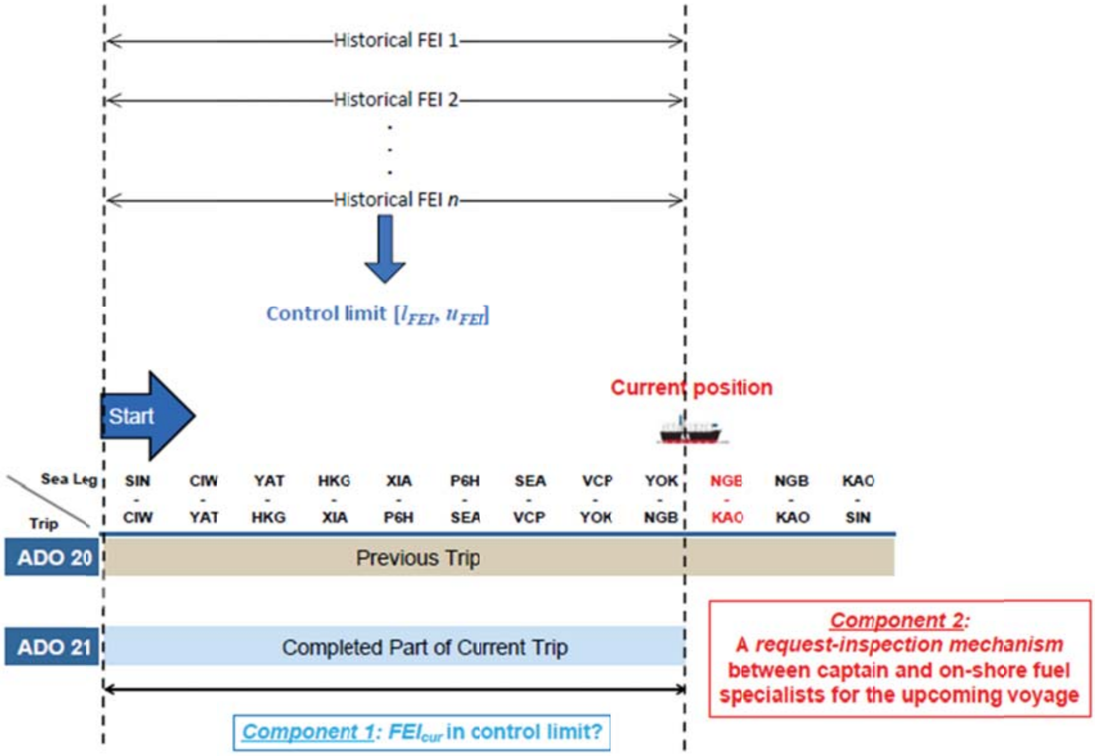

Figure 3: An in-service bunker fuel consumption management scheme for a containership

References

B P Pedersen, J Larsen (2009) Prediction of full-scale propulsion power using artificial neural networks. *Proceedings of the 8th International Conference on Computer and IT Applications in the Maritime Industries (COMPIT'09)*, Budapest, Hungary.

E B Beşikçi, O Arslan, O Turan, A Ölçer (2015) An artificial neural network based decision support system for energy efficient ship operations. *Computers & Operations Research*, In press.

Y Nakamura (2015) From eco-ships to eco-shipping and beyond. *Future-Ready Shipping 2015: A Joint IMO-Singapore International Conference on Maritime Technology Transfer and Capacity Building*, Singapore.

The implications of environmental regulation on sailing speed optimization

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1. Introduction

The contribution of maritime shipping in the global anthropogenic greenhouse gas emissions and the generation of air pollutants near coastlines and ports has led to increasing regulatory pressure to ship operators. The environmental performance of shipping is influenced by the decisions of regulatory bodies, ship operators, shippers, and port authorities. In previous years, speed optimization referred to the identification of the sailing speed that either minimizes fuel costs, or maximizes profit.

There are significant environmental and economic trade-offs emerging with the sailing speed of a vessel, as it maintains an exponential relationship with the total fuel consumption used for propulsion. Following the increase in fuel prices, slow steaming was used by the industry as a means to reduce operating costs. The issue of optimal sailing speed has resurfaced in academia as the new regulations that affect fuel costs for specific segments of the journey call for improved planning on sailing speeds. The most relevant regulation has been the designation of emission control areas (ECA) that dictate the use of low-sulphur fuel for ships sailing within these areas. This resulted in different optimal sailing speeds for vessels that switch fuel to comply with this regulation.

At the same time, port authorities have started considering the introduction of voluntary speed limits in the immediate proximity of the harbor, in order to reduce the amount of pollutant emissions in their surroundings. A common attribute of fuel policies and speed restrictions, is that both can result in increased fuel consumption in other geographical areas (e.g. outside the policy zone), and therefore essentially trade the environmental benefit in the regulated area with an environmental or economic penalty in the overall balance. This is depicted in Figure 1.

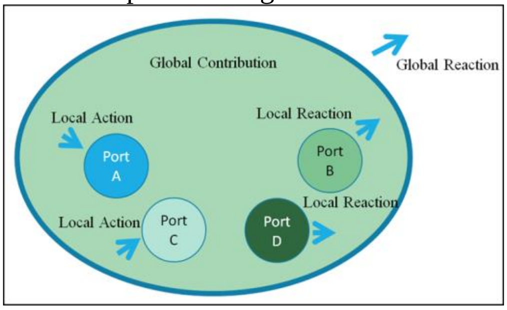

Figure 1: The environmental balance of shipping emissions reduction actions

Figure 1 presents schematically the global contribution of the maritime sector to anthropogenic emissions. This can be considered as a result of the individual contributions of vessel activity at each port, and the emissions generation during sailing of vessels between the ports. An emissions reduction action that is targeted in a local area (e.g. port A and port C) can lead to increased emissions in the global scale (Global reaction), or even additional emissions at a different port (ports B and D). This paper builds on a bottom-up activity based emissions modelling methodology and examines the environmental trade-offs presented in Figure 1. The paper is also formulating a non-linear convex optimization model that seeks to minimize fuel costs. The model is used for a vessel sailing a fixed sequence of port calls, assuming a versatile mixture of environmental regulations and voluntary programs with economic impacts to the vessel journey.

2. Background

This section summarizes the key findings of relevant work in the topic of speed optimization, and presents the main contribution of this paper.

2.1. Previous work

In recent years, and particularly following the designation of emission control areas (ECA), there have been a number of studies that suggested the change of speed when expensive fuel is used. Ronen (2011) conducts a literature survey and concludes that there has been relatively little research on optimization of sailing speed. In his work, he shows that oil price has a crucial role in the trade-offs between speed reduction and the associated necessary increase in number of vessels deployed to maintain frequency of service and transport capacity. Doudnikoff and Lacoste (2014) examine speed differentiation with lower sailing speeds within ECAs, and increased speed in non-regulated waters. Their model shows fuel cost savings of up to 3%, at the additional expense of 4.5% more CO2 emissions. However, the proposed model does not consider potential time delays, and it considers a basic cubic relationship between engine load and speed, completely disregarding the impacts of sailing speed on the specific fuel oil consumption (SFOC) of an engine. A more refined approach on speed optimization within ECAs is presented by Fagerholt et al. (2015), where the additional option of using scrubber systems instead of fuel switching is discussed. Their work contrasts the SO_x-CO_2 trade-off, and raise the issue of ship operators choosing longer sailing paths in order to avoid sailing within ECAs. The research question of reducing sailing time within regulated waters has been formulated by Fagerholt and Psaraftis (2015) as an optimization problem dubbed the ECA refraction problem.

2.2. Paper contribution

The previous papers have focused on speed differentiation due to increased fuel costs in segments of a port to port journey. However, the inclusion of voluntary speed limits in specific voyage segments has not been considered. These speed limits may result in increased sailing speeds in other areas so that vessels make up for lost time. An economic incentive is usually provided to participating vessels in speed reduction schemes. These aspects have not been considered in sailing speed optimization problems in previous studies. This paper proposes the formulation of a fuel cost minimization problem with sailing speeds at different journey segments as decision variables. A refined emissions modelling methodology is used in parallel that allows the construction of comprehensive emissions inventories for all segments of the journey. As a result, the proposed formulation can readily be adapted to account for the social costs of emissions and examine their implications on optimal sailing speed. The model is ran for a set of case studies based on real world data for different containerships, assuming different levels of flexibility for time delays in a specified sequence of port calls. The next section describes the methodology used in this paper.

3. Methodology

This section briefly presents the emissions modelling methodology used in this paper, and then a short version of the mathematical model used for the sailing speed optimization problem.

3.1. Modelling ship emissions

Most emissions modelling methodologies for maritime transport are using a so called bottom-up approach that matches ship activity with power demands. Ships usually have three types of machinery onboard; the main engines that are used for propulsion, the auxiliary engines that cover the electricity requirements of the vessel, and the auxiliary boilers that are used to maintain the main engines and fuel temperatures when the latter are switched off. This paper uses the emissions modelling methodology as developed in Zis et al. (2014) that first considered the potential of speed reduction schemes near ports. The fuel consumption FC (kg) of any engine i, onboard a vessel k, during activity j, can be estimated by equation 1, when the following information is known:

- nominal power installed $EP_{i,k}$(kWh),
- the engine load $EL_{i,j,k}$ (%) at which engine i operates,

- the specific fuel oil consumption SFOCi,j,k (g/kWh),
- the duration (time) of activity t(h) are known

$$FCi,j.k = 10{-}3 \cdot t \cdot EPi,j.k \cdot ELi,j.k \cdot SFOCi,j.k \quad (1)$$

Activity j can be either sailing (s), manoeuvring (m), or hotelling when the vessel is at berth (b). Most studies assume that during berth and manoeuvring a fixed energy demand is required and therefore use an average value for the engine load of the auxiliary engines and boilers that are operating. However, during cruise the engine load of the propulsion engine depends on the sailing speed. This is generally known as the propeller law, whereby there is an exponential relationship between engine load and speed, as in equation 2.

$$\frac{{}^{1}EL_{m,j,k}}{{}^{2}EL_{m,j,k}} = \left(\frac{{}^{1}V_s}{{}^{2}V_s}\right)^n \quad (2)$$

Where ${}^{1}EL_{m,j,k}$and ${}^{2}EL_{m,j,k}$ denote the continuous rating output of the engine at sailing speeds ${}^{1}V_s$ and ${}^{2}V_s$, and *n* is a unitless coefficient. In many studies a cubic relationship is assumed (therefore n=3), but for high speed containerships a larger value of up to 4.5 is proposed (Psaraftis and Kontovas, 2013). The fuel costs can be found by multiplied the estimated fuel consumption at each activity phase with the respective price of the fuel used. The fuel consumption of each engine during the different shipping activities can then be multiplied with appropriate emission factors to estimate emissions generation.

3.2. A convex optimization model for speed optimization in the presence of regulation

The proposed optimization model seeks to minimize total fuel costs for a roundtrip voyage where various environmental regulation apply in different legs of the voyage. Table 1 presents the notation used (a shorter version is presented in this extended abstract).

Table 1: Notation for the speed optimization problem

Indices	*Denotes*
k	Vessel
i	Engine
r	Part of the journey
p	Port to port leg of the journey
Sets	
K	Vessels operating in a shipping line fleet
E	Engine types (main, auxiliary)
R	Sum of all journey areas
Q^p	Sum of all journey areas within a port to port distance *p*. it follows that $\sum_{j=1}^{p} Q^j = R, \forall\, j \in P$
P	Sum of all port-to-port journey legs
Parameters	
P^r	Fuel price ($/ton) in area *r*
D^r	Distance (NM) of area r
Decision Variable	
$V_{r,k}$	Sailing speed (knots) in area r of ship k

The objective function (equation 3) to be minimized is the overall fuel consumption of all engines *i* within set E, of all vessels k within a set *K* of a fleet during sailing in all legs *r* of a set of R total legs.

$$Min\ (Fuel\ Cost) = \sum_{k\in K}\sum_{r\in R}\sum_{i\in E} P^r \cdot 10^{-6} \cdot \frac{D^r}{V_k^r} \cdot \left(EP_{i.k} \cdot EL_{i.k} \cdot SFOC_{i,k}\right) \quad (3)$$

Subject to $V_k^r \le V_{m,k}$ $\quad \forall r \in R, k \in K \quad$ (4)

$$V_k^r \ge 0 \qquad \forall r \in R, k \in K \quad (5)$$

$$\sum_{p\in P}\sum_{r\in Q^p} \frac{D^r}{V_k^r} + t_{del} = \sum_{i=1}^{p} \frac{D^i}{V_{s,k}^i} \qquad \forall p \in P, k \in K\,,\quad t_{del} \le t_{max} \quad (6)$$

$$\sum_{r\in R}\frac{D^r}{V_k^r} = t_{max} + \frac{1}{V_{s,k}} \cdot \sum_{r\in R} D^r \quad \forall r \in R, k \in K \tag{7}$$

Constraint 4 ensures that the sailing speed at any region r cannot exceed the maximum possible sailing speed $V_{m,k}$ of vessel k. Constraint 5 is a non-negativity constraint for all sailing speeds. Constraint 6 is ensuring that each vessel k arrives at port p at the expected time of arrival with an allowable delay t_{del} that cannot surpass t_{max} (the maximum allowed delay per port). The last constraint (eq. 7) dictates that the total trip duration is equal to the planned travel time plus any potential time delay allowance. Despite the non-linearity of the model, for small instances the problem can be easily solved with existing software tools (e.g. CPLEX and MS Excel solver). Additional constraints are used for the induction of speed limits in specific segments, and also to compare monetary gains by participation in such policies.

4. Results and conclusions

The proposed formulation is examined for a set of case studies containing different vessel types (in terms of carrying capacity), and different sailing schedules. The provision of a time delay allowance is also considered for different ports. The sailing speed in each segment within sequence of calling ports is optimized for the baseline case where only ECA are considered, and MGO is used within these waters. The model is subsequently used for the introduction of speed reduction schemes near some of the calling ports, for different specifications (length of speed limit zone, speed limit, monetary incentive). Preliminary results, using fuel switching between MGO (within ECA) and HFO in non-regulated waters, show that cost savings of up to 6.8% can be anticipated, but largely depend on the fuel price differential. However, for strict adherence to the schedule of port calls (no allowed delay), there are increased CO_2 emissions in the full service overall, in comparison with the as-published schedule with no speed differentiation. This finding agrees with previous work in the field of speed optimization when fuel switching is mandatory. The way a maximum delay allowance to each port call is distributed, varies significantly with the problem specification (fuel prices, environmental regulation in each leg) and very different environmental benefits are observed, ranging from 0.3 to 4% fuel cost savings. Environmental benefits are also observed when compared with the as-published sailing schedule of large containerships, which indicates that there is scope for significant environmental improvements in the operational level.

Key References

M Doudnikoff, and R Lacoste (2014). Effect of a speed reduction of containerships in response to higher energy costs in Sulphur Emission Control Areas. *Transportation Research Part D: Transport and Environment*, **28**, 51-61.

K Fagerholt, and H N Psaraftis (2015). On two speed optimization problems for ships that sail in and out of emission control areas. *Transportation Research Part D: Transport and Environment*,**39**,56-64.

K Fagerholt, N T Gausel, J G Rakke, and H N Psaraftis (2015). Maritime routing and speed optimization with emission control areas. *Transportation Research Part C: Emerging Technologies*, **52**,57-73.

H N Psaraftis, and C A Kontovas (2013). Speed models for energy-efficient maritime transportation A taxonomy and survey. Transportation Research Part C: Emerging Technologies, **26**, 331-351

D Ronen (2011). The effect of oil price on containership speed and fleet size. *Journal of the Operational Research Society*, **62**(1), 211-216.

T Zis, R J North, P Angeloudis, W Y Ochieng and M G H Bell (2014) Evaluation of cold ironing and speed reduction policies to reduce ship emissions near and at ports. *Maritime Economics & Logistics*, **16**(4), 1-28.

Tactical bunker management for operational flexibility and risk management in SECAs

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1. Problem Description

We consider a maritime routing and bunker management problem in a liner shipping context, under the new regional emission regulation and uncertain fuel prices. Introduced by IMO in 2005, the regional environmental regulation for Sulphur Emission Control Areas (SECAs)was recently upgraded in 2015. For vessels sailing inside the regulated areas, the latest version of SECA regulation restricts the level of sulphur content in the bunker fuel to maximum 0.1%. Therefore, the conventional marine fuel - heavy fuel oil (HFO), which has more than 3.5% sulphur content, is no longer permitted inside SECAs. This fact forces some shipping companies to switch to marine gasoline oil (MGO) in these areas, which has the compliant sulphur content level but a much higher price.

Bunker management decisions for a shipping company can be roughly divided into two levels, operational and tactical. On an operational level, the shipping company needs to decide how much fuel they should purchase from the spot market according to the operational parameters of a voyage, such as sailing speed and sailing distance. On the other hand, since fuel prices are highly volatile, the shipping company sometimes also needs to do tactical fuel hedging in the forward market so that the risk and cost volatility can be controlled. The hedging instrument considered in this paper is marine bunker swap (Wang and Teo, 2013). Besides the additional fuel type involved in bunker management, the SECA regulations may also lead to changes in a ship's sailing behavior (Fagerholt et al., 2015). For instance, if a vessel needs to sail from port-A to port-B while both ports are located inside the same SECA, it may choose to exit the SECA zone from port-A, sail along the edge of the SECA and then re-enter the zone when approaching port-B, rather than sailing the shortest straight route between the two ports. Although such change in sailing behavior may lead to a longer sailing distance and require a higher speed to stay inside the time window, it avoids a substantial involvement of SECA sailings and thus reduces the need for expensive MGO, with, however, a higher HFO consumption outside the SECA. As a whole, this may result in a lower total fuel cost, but higher emissions. However, such behavioral changes in sailing patterns will affect the bunker management between the two fuels. Similarly, different fuel strategies will also affect the optimal sailing behavior in future operations. Hence, with the complexity of marine bunker management increasing dramatically after SECAs were introduced, we aim to use stochastic programming to analyze the optimal bunker management strategy under all the circumstances mentioned above.

2. Mathematical Model

A two-stage stochastic mathematical programming model has been formulated. The model concerns a specific liner service with fixed route and schedule. We define a ***loop*** as a round trip service consisting of several legs, where a ***leg*** refers to the sailing voyage between two ports in the loop. A ***leg option*** then represents one of the candidate routes for sailing the leg. The first stage in the model represents the trading in the forward markets for fuel, while the second stage takes care of route choices and fuel purchases in the spot market (and hence, as a consequence, use of the forward contracts. The model is run with and without risk aversion. CVaR is used to represent risk aversion when present.

The objective is to minimize the sum of the total forward fuel costs and the total *expected* spot fuel costs. There are time window limitation for each sailing. Speed is discretized. There is a penalty for unused fuel in the forward contracts.

3. Results and Discussions

The preliminary results of this research show that optimal bunker management strategies for shipping companies have changed after SECAs were introduced. Second, the results also show a substantial value of involving changes of sailing behavior when considering the SECA regulations. Third, different hedging decisions will lead to different sailing behavior in future operations. The major contributions of this paper is as follows: First, it fills the gap of the present literature where only very few studies include both tactical and operational considerations in marine bunker management. Second, it integrates the traditional fuel management problem in the shipping industry with the new SECA regulations. In particular, we demonstrate that tactical fuel operations in the forward market cannot be made in a good way unless operational decisions are included in the calculations. This is very natural from a stochastic programming perspective, but was not very important in the liner industry before SECAs were introduced. So tactical operations in the forward markets are not only useful to control risk, but also to achieve operational flexibility when spot prices are volatile.

References

Andersson, H., Fagerholt, K., Hobbesland, K., 2015. Integrated maritime fleet deployment and speed optimization: case study from RoRo shipping. Comput. Oper. Res. 55, 233-240.

Fagerholt, K., Gausel, N.T., Rakke, J.G., Psaraftis, H.N., 2015. Maritime routing and speed optimization with emission control areas. Transportation Research Part C, 52, 57-73.

Wang, X., Teo, C.C., 2013. Integrated hedging and network planning for container shipping's bunker fuel management, Maritime Economics & Logistics, 15, 172-196.

13:30 – 15:30 **Session 4A (Floor 17)** **Chair: Persa Paflioti**

Theme: Ports (Models for optimising port or terminal operations)

Collaborative Subcontracting Delivery Requests for Inter-Terminal Transshipment Containers
Dongwon Jang, Benedikt Vornhusen and Herbert Kopfer

Investigating Alternative Approach to the Gravity Model of International Trade in Evaluating International Trade Policies
Collins Teye, Michael G. H. Bell and Persa Paflioti

Massively Parallelising Genetic Algorithms on Apache Spark to Schedule Straddle Carriers
Haye Lau and Shuai Yuan

A Simulation Optimization based Platform for Container Port Capacity Planning
Haobin Li, Chenhao Zhou, Loo Hay Lee and Ek Peng Chew

Collaborative contracting for delivery requests of inter-terminal transshipment containers

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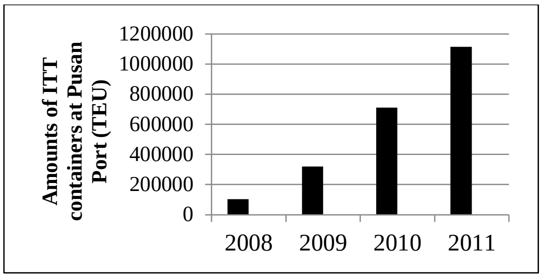
1. Introduction

In addition to inbound and outbound container flows, ship-to-ship transshipment flow of containers is becoming more and more important. There are two different types of this handling operation: inner- and inter-terminal transshipments. In case of inner-terminal transshipment, a discharged container must be moved in order to be reloaded on its designated vessel at the same terminal where it has been discharged. However, a container for an inter-terminal transshipment operation must be transported to an adjacent terminal for reloading on the designated vessel. That is, discharging and reloading terminals for the same container are different from each other. This study focuses on transportation for Inter-Terminal Transshipment (ITT) containers between different terminals. For Pusan port in Korea which is one of the busiest ports in the world, the importance and amount of ITT containers are growing due to the increasing frequency of calls of mega-vessels as shown Figure 1. Despite an increased container flow, there is a crisis due to the increase of transportation costs which are caused by non-coordinated and inefficient carrier-operations. Furthermore, major ship-liners have requested high-quality service of the transportation with lower costs (Park and Gong 2014; KRRI 2012). This study addresses the transportation problem of ITT containers considering resource and profit sharing to maximize the total profit of all participating carriers in a coalition. The developed approach could contribute to increase the efficiency of Pusan port which has suffered from decreasing operation profits of carriers during the last few years.



(a) The latest amounts of ITT containers

	2010	2020	2030
Total amounts of containers	262,072 RT	416,721 RT	629,382 RT
ITT containers	236,636 RT	376,954 RT	584,628 RT
	14,194 TEU (100%)	22,354 TEU (157%)	34,630 TEU (244%)

(b) The expected amounts of ITT containers

Figure 1: The latest and expected amounts of inter-terminal transshipment containers at Pusan Port (KRRI 2012)

2. Collaborative ITT transportation through resource and profit sharing

This study assumes that all carriers agree to a collaborative ITT transportation, which means to share their own delivery requests (ITT containers), information and vehicles if necessary. The objective of this study is to maximize the total profit of all carriers and to increase the efficiency of the whole port operation. The results of this study show that collaborative transportation with resource and profit sharing is a powerful means to reduce transportation costs for all carriers. This study is based on the following assumptions.

- Delivery requests are known and ready on their pickup locations at the beginning of planning
- Distance between pickup and delivery locations are known at the beginning of planning
- Vehicles are ready on their own depot at the beginning of planning
- Each vehicle carries out only one delivery request (20ft/40ft/45ft) at one time (capacity = 1)
- Handling operation of delivery requests includes loading at pickup location, unloading at delivery location and waiting at pickup and delivery locations.

This transportation problem is referred to as pickup and delivery problem with full-truckload (PDP-FTL) because all carriers handle their own ITT containers with a limited number of vehicles, respectively. A mathematical model with time-windows and an approach considering reallocations based on a genetic algorithm are suggested to solve this problem. Carriers expect that the total transportation costs will be reduced by forwarding some of their delivery requests to another carrier by contracting in a coalition. Figure 2(a) shows a process to determine the contracting prices. Reallocation of carriers' own ITT containers is a kind of contract in a coalition. If the transfer price announced by transferor is larger than that of transferee then the contracting price can be calculated by [transfer price – ((transfer price – takeover price) × α)]. The initial value of α is one; $0\leq\alpha\leq 1$. On the other hand, if the takeover price suggested by transferee is larger than that of transferor then the transferee can be asked to negotiate for the contracting price to transferor by using adjusting ratio; $0\leq\beta\leq 1$. The initial value of β in this study is set on 0.5. Contracting price can be set as [transfer price + {(takeover price - transfer price) × β}. A larger value of β makes an offer of the contracting price close to the takeover price supposed by transferee. At this time, if the transferor does not want to adjust between two different prices then the reallocation for the delivery request is cancelled. The various parameter values of α and β can be analyzed by numerical experiments. As shown in Figure 2(b), the length of chromosomes depends on the total number of delivery requests; and the locus of the chromosome indicates the delivery request number (#). Randomly generated digit values of chromosomes illustrate individual carriers. Assume a randomly generated chromosome is 2,1,2,2,1,2,3,2,3. Then, delivery request #2 and #5 are assigned to carrier #1. In the same way, carrier #2 and #3 have a set of delivery requests {1,3,4,6,8} and {7,9}, respectively. A fitness value (the total transportation costs) of generated a chromosome is evaluated by routing of vehicles. The total profits (total revenue – total transportation costs) of all carriers can easily be determined by summing up $profit_1$ (profit by transportation fulfilment) and $profit_2$ (profit by forwarding own delivery requests) for each carrier. In the approach based on genetic algorithms, a roulette wheel selection, a uniform crossover, and a mutation operation are applied for the next generation's population.

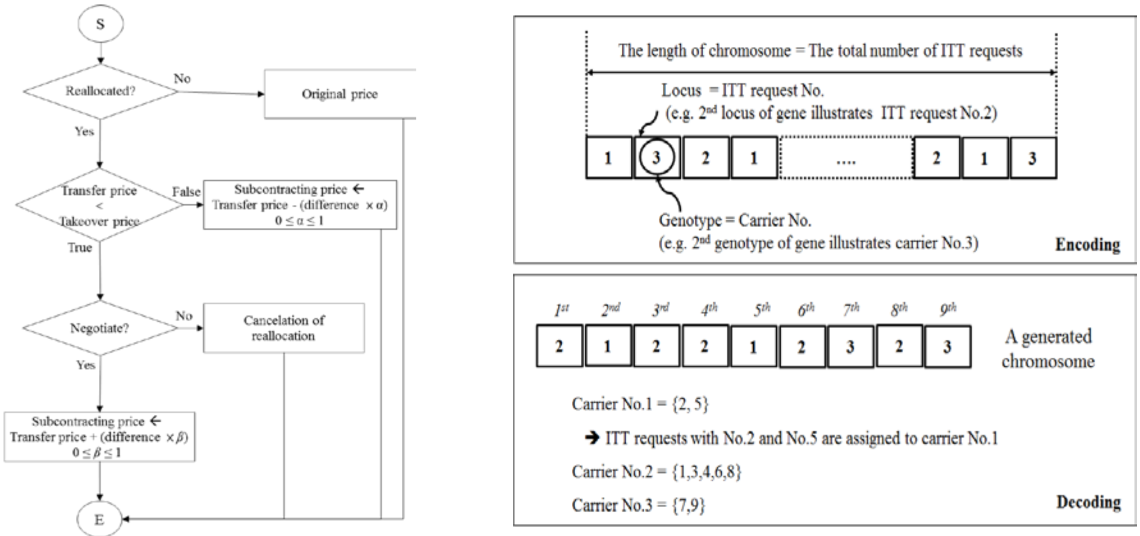


Figure 2: (a) Process determining the contracting prices and (b) expressions of chromosomes

3. A simple instance for collaborative ITT transportation

In this example it is supposed that the total number of carriers is n^c =3, the total number of delivery requests is n^t =18, the total number of vehicles is n^v =6, the original price of delivery request j is c^o_j=20 for all j, the unit cost of the loaded travel transportation for a delivery request by carrier i (unit: €/km) is c^{LT}_1=c^{LT}_2=c^{LT}_3=0.39, unit cost of the empty travel transportation for a delivery request by carrier i is c^{ET}_1 =c^{ET}_2=c^{ET}_3=0.37. The loaded travelling distance of delivery request j is d^L_j, the empty travelling distance between delivery location of request t and pickup location of request j is d^E_{tj} which is calculated from pickup and delivery location according to the distance matrix as shown Table 1.

The handling operation time at yard-block considering waiting time of each delivery request within pickup and delivery terminals is p_i, working time (480min/day) of each vehicle, and average velocity of vehicles on roadway (v=40km/h) are given. Each request has a time window [0, 480] for delivery. Table 2 shows the optimal solution calculated by CPLEX (commercial solver) of transportation costs for each carrier with originally assigned delivery requests and for central planning. In case of central planning for all delivery requests, computational time increases exponentially; ≥3600 secs with 2.3% gap from optimum. In all cases (re)assignment of the requests for each carrier, the total profit cannot exceed the optimum profit of central planning. The quality of GA solutions was measured through comparison with those of small instances generated by CPLEX.

Table 1: An example with real-distances between terminals and ITT delivery requests

Terminal	Depot	A	B	C	D	E
Depot	0	7.1	5.7	1.2	0.7	2.8
A	7.1	0	1.4	5.9	7.8	9.9
B	5.7	1.4	0	4.5	6.4	8.5
C	1.2	5.9	4.5	0	1.9	4.0
D	0.7	7.8	6.4	1.9	0	2.1
E	2.8	9.9	8.5	4.0	2.1	0

Request No.	Pickup and Delivery location	Handling time (min)
1, 2,18	A → B	33
3,16,17	A → C	39
4, 5,15	C → A	39
6,13,14	B → A	33
7,12	B → C	30
8,11	B → D	41
9,10	E → B	42

Table 2: The optimal solutions for the isolated planning of carriers' own original requests and central planning of all requests and vehicles integrated

Isolated planning (CT: ≤ 1 sec. / gap: 0%)					Central planning (CT: ≥ 3600 sec. / gap: 2.3%)			
C#	Request	V#	Route (Total cost: 63.664)	Profit *(296.336)*	Request	V#	Route (Total cost: 38.134)	Profit *(321.866)*
1	{1,2,3,16,17,18}	1	-	102.468	{1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18}	1	9→7→5→2→6→3→12→13→18→11 (20.732)	321.866
		2	1→16→17→18→2→3 (17.532)			2	-	
2	{6,7,8,11,12,13,14}	3	14→6→8 (6.992)	120.24		3	-	
		4	-			4	-	
		5	12→7→13→11 (12.768)			5	10→14→16→4→17→15→1→8 (17.402)	
3	{4,5,9,10,15}	6	10→15→5→4→9 (26.372)	73.628		6	-	

Table 3: Transfer (shading cells) and takeover prices of each request by each carrier (ex. within 25%)

Req.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Price	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
C1	17.38	15.17	16.73	17.32	15.54	16.05	17.28	17.35	19.35	19.08	15.36	15.91	15.09	17.56	19.17	15.19	15.97	17.50
C2	15.60	17.83	16.85	19.65	18.56	15.62	20.00	16.98	16.02	18.15	19.12	19.57	19.77	17.63	19.86	18.87	19.88	19.74
C3	16.23	16.00	16.44	16.86	16.57	18.53	19.19	16.77	16.83	17.85	15.11	18.05	19.87	16.02	19.10	18.25	18.23	16.52

Assume that the prices for all delivery requests by all carriers are given for contracting as shown in Table 3. The prices of shading cells indicate the transfer prices for each carrier's own requests. For example, request #3 can be reallocated to carrier #3 however it is not allowed to assign it to carrier #2 without negotiation. In the approach, the size of generation and population is 500 and 100, respectively. Crossover ratio, mixing ratio for uniform crossover, and mutation probability is 0.8, 0.7, and 0.01, respectively. Table 4 shows the variations for the profits of carriers' own original requests (isolated planning in Table 2) and those of their reallocated requests through forwarding of some delivery requests in case of α is 1 and without negotiation. That is, contracting prices are determined by each transferor. The values of prices are randomly generated within 5%, 15%, 25% and 50% from original prices. The total transportation cost fall off down to 36.5% as well as the total profit rises up to 7.8% compared to the optimum of isolated planning. The gap of the total profits to the optimum of central planning results in only 0.71%. Table 5 shows effects of collaborative ITT transportation with randomly generated instances. The results show the average gap of 2.269% to the optimum of central planning.

Table 4: The variations of the profit of each carrier with reallocated requests considered contracting prices (ex. α=1 and no negotiation, gap from the optimum of central planning)

Prices range	Total costs (opt. : 38.134)		Total profits (opt. : 321.866)		C#	Reallocated set of requests	Revenue	$Profit_1$	$Profit_2$
5%	41.464	8.73%	***318.536***	***1.03%***	1	{3,4,5,7,12,15,16,18}	158.43	138.616	1.7
					2	{1,6,8,9,11,13,14}	140.01	124.398	0.94
					3	{2,10,17}	61.559	50.242	2.639
15%	45.312	18.82%	***314.688***	***2.23%***	1	{2,3,9}	67	49.362	8.97
					2	{1,8,11,12,13,14,18,}	138.27	119.308	3.63
					3	{4,5,6,7,10,15,16,17}	154.72	131.458	1.96
25%	40.428	6.01%	***319.572***	***0.71%***	1	{2,5,13,16,17}	101.44	79.564	10.81
					2	{6,12}	57.82	34.628	17.82
					3	{1,3,4,7,9,10,11,14,15,18}	200.74	172.29	4.46
50%	40.576	6.4%	***319.424***	***0.76%***	1	{1,5,9,13,16,17,18,}	133.98	105.328	14.28
					2	{2,3,4,6,7,8,10,11,12,14,15}	186.34	154.836	5.3
					3	∅	39.68	0	39.68

Table 5: The effects of the collaborative ITT transportation (ex. α=1 and no negotiation, range of original prices = 25%)

Instance	Isolated Planning		Central Planning		Reallocation by GA			
	Total cost	Total profit	Total cost	Total Profit	Total cost	Cost reduction from isolated	Total Profit	Gap from central
1	36.83	263.17	30.99	269.01	35.048	4.84%	264.952	*1.508%*
2	52.60	247.40	38.65	261.35	48.120	8.52%	251.880	*3.623%*
3	37.51	262.49	28.54	271.46	36.250	3.36%	263.750	*2.840%*
4	51.43	248.57	41.65	258.35	49.315	4.11%	250.685	*2.967%*
5	56.71	243.29	45.35	254.65	50.252	11.39%	249.748	*1.925%*
6	50.08	249.92	36.68	263.32	42.939	14.26%	257.061	*2.377%*
7	33.38	266.62	26.20	273.80	30.210	9.50%	269.790	*1.465%*
8	49.42	250.58	36.36	263.64	42.182	14.65%	257.818	*2.208%*
9	41.47	258.53	33.85	266.15	38.693	6.70%	261.307	*1.820%*
10	36.36	263.64	25.42	274.58	30.793	15.31%	269.207	*1.957%*
						9.26%		*2.269%*

4. Conclusions

This study addresses the effect of a collaborative inter-terminal transshipment transportation considering resource and profit sharing. An approach based on genetic algorithms is suggested to maximize the total profit of all carriers. In future research, a comprehensive analysis based on practical data is needed by varying the parameters for contracting and genetic algorithms. Collaborative ITT transportation through forwarding of requests is effective to reduce the transportation costs. For further research, fair profit sharing for all carriers under the integrated operation is discussed. Different sizes of vehicles (≥ 1 capacity) or different types of vehicles (own, mandated, rental), and additional resource (trailer, chasses) should be considered.

Acknowledgement
This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (2015R1A6A3A03019652)

References

Korea Railroad Research Institute (2012) Research and development of inter-terminal transshipment transportation system, *Korea Institute of Marine Science & Technology Promotion Final Report*.

N G Park, and Y D Gong (2014) Collaborative study for designing and operation of ITT platform at the Pusan New Port, *Busan Port Authority Final Report*.

INVESTIGATING ALTERNATIVE APPROACH TO THE GRAVITY MODEL OF INTERNATIONAL TRADE IN EVALUATING INTERNATIONAL TRADE POLICIES

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ABSTRACT

The gravity model is considered one of the most successful empirical models in economics and is the workhorse for international trade policy evaluation. The so-called 'gravity with gravitas' (GWG) model proposed by Anderson and Van Winoop (2003) and subsequent extensions of it constitute the state-of-the-art. In this paper we show that the GWG model can be reformulated as discrete choice models. We also present formulae for elasticities and show how the proposed model can be used in forecasting. Implementation of these model types on the published data set reveals the advantages of the logit model formulation over the gravity model in terms of model fits, forecasting and policy evaluations.

1 INTRODUCTION

The Gravity model is considered one of the most successful empirical models in economics, and the workhorse for international trade policy evaluation (Channey, 2011; Shepherd, 2012). It has been successfully applied to estimate the impacts of various trade-related policies ranging from traditional tariffs to new behind-the-border measures (Shepherd, 2012). As noted in Leamer and Levinsohn (1995) the gravity equation is one of the most stable empirical relationships in economics due to its ability to correctly approximate bilateral trade flows. The earliest work on the use of gravity theory to describe the pattern of bilateral aggregate trade flows between two countries was due to Tinbergen (1962). The theory asserts that the trade flows between country *i* and country *j* is proportional to the product of the gross national products (GNP) of the two countries and inversely proportional to the square of the distance between them:

$$T_{ij} = C * (GNP_i)^{\alpha} * \left(GNP_j\right)^{\beta} * d_{ij}{}^{\gamma} \qquad (1)$$

Taking the natural logarithm of equation (1) the gravity model can be expressed as:

$$InT_{ij} = InC + \alpha In(GNP_i) + \beta In\left(GNP_j\right) + \gamma In\left(d_{ij}\right) + \varepsilon_{ij} \qquad (2)$$

where ε_{ij} is the error term and assumed to be independent and identically distributed (i.i.d.).

Several empirical works have shown that the values of the first two parameters ($\alpha, \beta \approx 1$) are relatively stable over time and across different samples of counties (Channey, 2011; Shepherd, 2012). What actually distinguishes one gravity model from another in the literature is the interpretation or specification of the distance variable. Some applications use the pure distance between the two counties (Shepherd, 2012). Others use a deterrence function involving distance and other policy or geographical variables such as common language or common border (Tinbergen, 1962)

In the original paper by Tinbergen (1962), T_{ij} represents the size of trade between any pair of counties, GNP_i is the amount of export of country i and is measured in terms of gross national product; GNP_j is the importing market approximated also by gross national product of country j. The term d_{ij} consists of both geographical distance between the two counties (in 1,000 nautical miles), a dummy term (N_{ij}) that captures whether or not countries share a common land border, and a dummy term (V_{ij}) representing trade agreement between the two countries. Incorporating these into equation (2) we have:

$$InT_{ij} = InC + \alpha In(GNP_i) + \beta In\left(GNP_j\right) + \gamma_1 In\left(d_{ij}\right) + \gamma_2 N_{ij} + \gamma_3 V_{ij} + \varepsilon_{ij} \tag{3}$$

Much empirical work on gravity models takes the form of equation (3), with an emphasis on the relevance and importance of certain policy variables on international trade. For example, Rose (2000) investigated the effect of two countries having the same currency. The work by McCallum (McCallum, 1995) looked at the effect of borders on bilateral trade with Frankel and Egger (2004) focusing on the effect of free trade agreements (FTA). The gravity model used by Egger and Pfaffermayr (2003) included dummies for individual country-pair and time dummies to control for common shocks.

In all the above studies, the gravity model was used to explain why bigger countries trade more and more distant counties trade less, making it a powerful tool for evaluating international trade policy. However, there are at least two known problems associated with the basic formulation of the gravity model that are at odds with standard economic theory as noted in Shepherd (2012):

1. The gravity model assumes that the cost of trading between any two counties is only affected by economic factors in those two counties. Mathematically

   $$\frac{\partial \log T_{ij}}{\partial \log C_{ik}} = 0 \; \forall \; k \neq j \tag{4}$$

   For example, consider the impact on trade between countries A and B resulting from a change in trade costs between countries A and C. An example of such a change might be that countries A and C enter into a preferential trade agreement that lowers tariffs on their respective goods. Basic economic theory suggests that such a move may well impact A's trade with country B, even though it is not party to the agreement

2. The gravity model also assumes absolute utility. What this implies is that if we consider equal increase in costs across all trading routes with no change in relative prices, the model will still predict a proportional decrease in trade across all bilateral routes.

The above limitations led several researchers to seek for alternative formulation of the gravity model that relaxes the above assumptions and also has sound theoretical microeconomic foundations. One such model that attracted a lot of attention in academia recently is the 'gravity with gravitas' model proposed by Anderson and Van Winoop (2003). This formulation extended the basic gravity model to include terms capturing both inward and outward multilateral resistance, effectively solving the problems identified in the basic gravity model. However these extra terms are unobserved and do not correspond to any price indices collected by any statistical agencies making the model difficult to estimate and apply in practice. In fact the implementation of this model type is not different structurally from the basic model with addition of extra dummy variables to account for bi-literal or multilateral resistances (Shepherd, 2012).

2 GRAVITY MODEL AND LOGIT MODELS

In this section we reformulate the gravity model as a logit model. From equation (1), the total trade for country *i* (T_i) over all its trading partners (countries) $j \in N_i$, where N_i is the number of countries trading with country *i*, can be derived by;

$$T_i = \sum_{j\in N_i} T_{ij} = \sum_{j\in N_i} \left(C * (GNP_i)^{\alpha} * \left(GNP_j\right)^{\beta} * d_{ij}{}^{\gamma}\right) \tag{5}$$

Eliminating C from equation (1) we obtain:

$$T_{ij} = T_i \frac{e^{\left(\beta InGNP_j + \gamma Ind_{ij}\right)}}{\sum_{j\in N_i} e^{\left(\beta InGNP_j + \gamma Ind_{ij}\right)}} = T_i \frac{e^{V_{ij}}}{\sum_{j\in N_i} e^{V_{ij}}}$$

Where V_{ij} is the utility of country *i* trading with country *j*, which in this example is expressed as:

$$V_{ij} = \beta InGNP_j + \gamma Ind_{ij} \tag{6}$$

and the probability of trading going to country *j* is:

$$P_{ij} = \frac{e^{V_{ij}}}{\sum_{j\in N_i} e^{V_{ij}}} \tag{7}$$

It is also easy to show that the Tinbergen (1962) gravity model can be obtained by simply extending the utility equation (7) to include common boundary and trade dummies:

$$V_{ij} = \beta InGNP_j + \gamma Ind_{ij} + \gamma_2 N_{ij} + \gamma_3 V_{ij}$$

Indeed, with appropriate specification of the utility equation, all gravity models can be expressed as a Multinomial Logit (MNL) model. The expected utility or logsum (William, 1977) of country i over all its trading nations is:

$$I_i = \sum_{j\in N_i} e^{V_{ij}} \tag{8}$$

Thus from (5) the amount of trade by any given country can be estimated using:

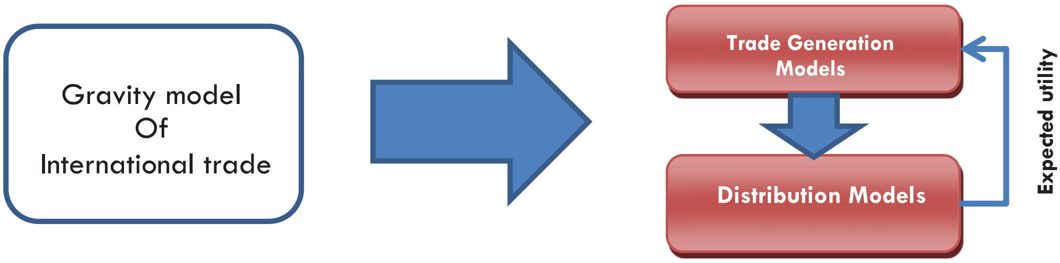
$$T_i = InC + \alpha * In(GNP_i) + \theta I_i \tag{9}$$

The trade generation mode (equation 9) can also be generalised to include many country specific variables:

$$T_i = \delta + f_i + \theta I_i \tag{10}$$

where $f_i = \alpha * In(GNP_i) + \cdots$

and θ $(0 \leq \theta \leq 1)$ is called structural parameter connecting the trade distribution model (TDM) with trade generation model (TGM).



3 CONCLUSION

This paper promotes the use of discrete choice models as a promising alternative approach to the gravity model for evaluating international trade policies. We have successfully demonstrated how logit models can be used to evaluate international trade policies. Once the parameters in the gravity model are estimated, the resulting model can be converted into logit models for forecasting and policy testing. Logit models are known to be flexible and underpinned by strong economic theory. They also exhibit desirable properties, such as differential sensitivities which ensure that probabilities are always positive and do not change if the utility of all the alternatives are increased by a constant, and direct and cross elasticities or differentials which ensure that increase the probability of trading with one country necessitates decreasing the probability of another country. Also the basic gravity model and its extended version, gravity with gravitas, are special cases of the logit model. What this means is that any benefits derived from using the gravity or gravity with gravitas models can also be derived from using a logit model.

4 REFERENCES

Anderson JE, van Wincoop E (2003), Gravity with Gravitas: A solution to the border puzzle. Am Econ Rev 63: 881-892.

Chaney, Thomas. 2011. “The Gravity Equation in International Trade: An explanation,” NBER WP 16753.

Leamer, E., and J. Levinsohn. 1995. “International Trade Theory: The Evidence” in G. Grossman and K. Rogoff (eds.) *Handbook of International Economics*. Amsterdam: Elsevier.

McFadden, D. (1974), ‘Conditional logit analysis of qualitative choice behavior’, in P. Zarembka, ed., *Frontiers in Econometrics*, Academic Press, New York, pp. 105–142.

Shepherd, B. 2012, ‘The Gravity Model of International Trade: A user guide, Retrieved: 21 March, 2014 from www.artnetontrade.org.

Tinbergen, Jan. 1962. “An Analysis of World Trade Flows,” in Shaping the World Economy, edited by Jan Tinbergen. New York, NY: Twentieth Century Fund.

Massively parallelising genetic algorithms on Apache Spark to schedule straddle carriers

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Extended abstract submitted for presentation at the
6th International Conference on Logistics and Maritime Systems (Sydney, 21-23 June, 2016)

1. Introduction

This paper presents an exploratory study into combining Parallel Genetic Algorithms (PGA) and Apache Spark, a state-of-the-art framework for large-scale computing, to solve the scheduling problem of efficiently allocating container moves to straddle carriers. This combinatorial optimisation problem, which lies at the heart of many automated vehicle deployments, cannot be solved perfectly in practice, because of the efficiency of a schedule depends on its complete set of task assignments. Previous works have shown that it is possible to practically improve on the plan quality compared to what is currently commercially available (Yuan et al, 2013, Skinner at al, 2013), but the challenge of computing the plans within the tight response times needed for efficient vehicle execution remains. As terminals grow to deploy ever larger fleets of automated vehicles (in the hundreds or more), a shift away from the local computing (or local computing cluster) paradigm may well become a necessity.

The study aims to examine the steps necessary to take advantage of the potentially massive computational resources harnessed by Apache Spark, a general engine for large-scale data processing, to perform the optimisation needed to generate highly efficient plans. If time allows, the feasibility of generating plans for massive vehicle fleets using this method will also be examined and discussed.

2. Planned Methodology

This study commences at the start of 2016. An approach to deploy genetic algorithms on the Apache Spark platform will be formulated. While internally this framework will be integrated with the fitness function used in the existing AutoStrad scheduling product, for clarity of presentation, the use of this approach against an analogous generic problem (e.g. pickup and delivery) may be discussed instead. Performance results such as convergence time with respect to the differing scales of computational resources (small local clusters, larger cloud deployments), as well as other practical points of note, will be presented.

3. Results and Conclusions

Preliminary results are not yet available; results anticipated to be available by April 2016.

4. Note to organisers

Please excuse the brevity of the abstract as the talk concerns an internal company-funded project that is yet to officially commence, but will be completed in time of the conference. As actual results arrive we will be better able to formulate a revised abstract. We sincerely hope this is acceptable.

References

S Yuan, B Skinner, S Huang, D Liu (2013) A new crossover approach for solving the multiple travelling salesmen problem using genetic algorithms, *European Journal of Research*, 228(1), 72-82

B Skinner, S Yuan, S Huang, D Liu, B Cai, G Dissanayake, H Lau, A Bott, D Pagac (2013) Optimisation for job scheduling at automated container terminals using genetic algorithms, *Computers & Industrial Engineering* **64**(1), 511-523

A Simulation Optimization based Platform for Container Port Capacity Planning

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1. Introduction

The Port of Singapore is widely acknowledged as the world busiest container transhipment port with over nearly 30 million containers handled every year. Currently the port consists of four major city terminals – Pasir Panjang, Keppel, Brani and Tanjong Pagar. To support transhipment operations, there is often a need to move containers between these terminals by trucks, which brings additional handling time, operational costs for port operations, as well as congestion on roads. Hence the government plans to consolidate all its container operations at one terminal in Tuas area and the expected capacity is 65 million TEUs per year.

Planning for a huge terminal is very complicated which involves many aspects such as terminal dimension, berth allocation strategy, equipment selection and deployment, etc. In order to test and find the best configuration among the proposed configurations to support decision makers, a simulation optimization based platform for container port capacity planning is desired.

Instead of modelling every detailed operational information, this simulation model focuses on planning level problem: how many resources are needed, what the parameters are, what strategies can be applied, etc. In this case, the simulation is modelled as a multi-server and multi-layer queuing system.

To be more specific, each container is considered as a customer, and every layer of the process is modelled as a multi-server queuing system with restricted resources, e.g., quay cranes, yard cranes and vehicles between berth and yard, and between yard and gate. In such a case, the number of servers and service time at each server depends on the equipment configurations, and the queuing rules is influenced by the operational strategy. The aim of the planning platform is to evaluate the capacity of a given port design, selecting the best configurations and strategies that lead to the highest performance at the lowest cost.

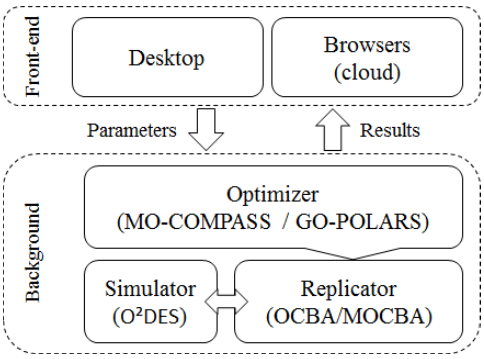

Figure 1: Structure of the port capacity planning platform

2. Methodology

As shown in Figure 1, the planning platform provides a front-end that is designed for the users to set up scenarios and conduct data analysis; and at the background, the simulation optimization modules consists of three part: simulator which is to evaluate the performance of a given system configuration, replicator which is to obtain optimal configurations from a finite set based on multi-run simulation estimation, and optimizer that is to navigate through a large-scale solution space.

2.1. Simulator in O²DES

Discrete event simulation (DES) has been widely adopted in many industrial realities as the main tool for evaluation of the system performance. There are many commercial software providing a graphical interface and animation features for the users to build and understand the dynamics of the system, such as Arena, AutoMod, FlexSim, etc. However, these software mainly focus on improving the ease of building models and data analysis, and it is very difficult to extract detailed information from the software, not to mention incorporating the recent advances in the simulation optimization.

Object-Oriented DES (O²DES) is an open source simulation framework based on .NET Framework technology which implements the object oriented paradigm in the scope of ease the development of discrete event simulation models (Li et al., 2015b). It offers several functionalities which support the integration of the tool with optimization techniques. It also supports the application of different variance reduction techniques such as budget allocation and time dilation.

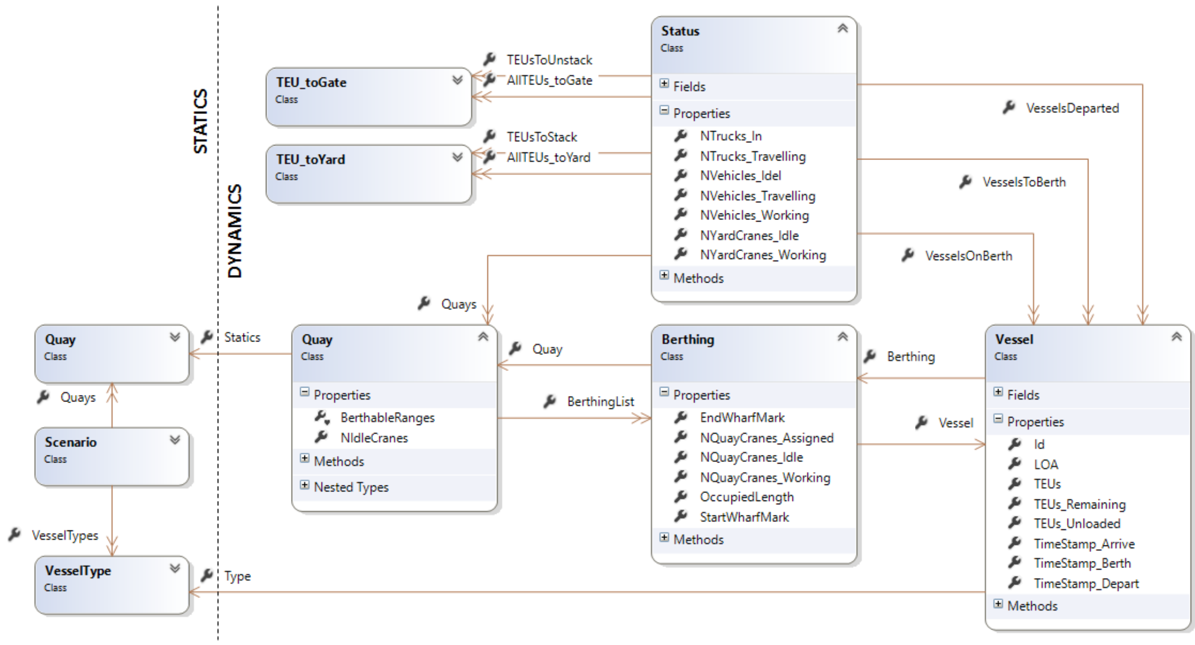

Figure 2: The static & dynamic components in O²DES simulator

From the O²DES paradigm, the simulator can be decomposed into three part of information, i.e., the statics that describes the system to be simulated, dynamics that provides a snapshot status at any time of the simulation run, and events that specify the time and logic of how the status should be updated. Figure 2 illustrates how the paradigm fits into the problem of container port capacity planning, in term of static and dynamic components; and Figure 3 shows all the events and their triggering relationship. Moreover, Figure 3 also illustrates three of the main workflows in the container port, i.e., the vessel arrival and departures, movement of inbound and outbound containers, and how they are simulated by executing a sequence of events. According to the O²DES paradigm, the simulator can be formulated once the three parts of information are defined.

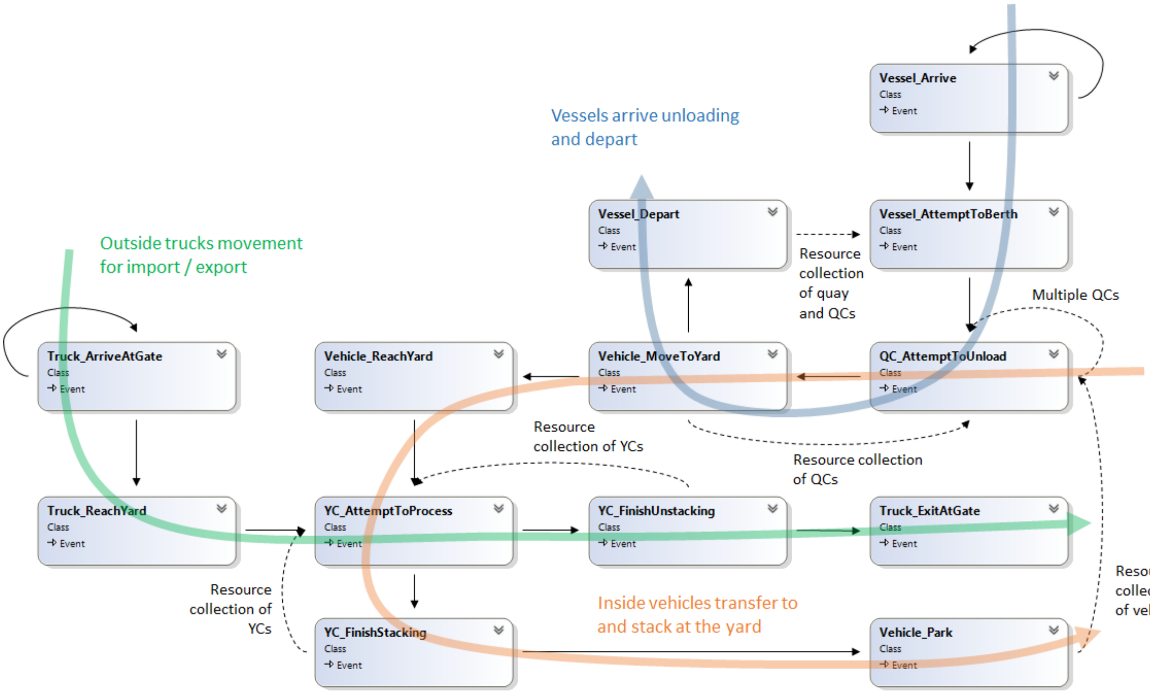

Figure 3: The events in O²DES simulator

2.2. Replicator with OCBA / MOCBA

With the simulation model, one of the problems is to determine the most efficient configuration, e.g., type and allocation of equipment, which satisfies required capacity. Since the simulation is stochastic in nature, optimal computing budget allocation (OCBA) (Chen, 1995; Chen and Lee, 2010; Chen et al., 2009) can be applied to determine how to replicate the simulation runs for each candidate system configuration that is given, such that the optimal configuration can be selected with least computation effort. However, we notice that the container port capacity planning is more than a simple best-selection problem, since the solution is constrained at certain performance criteria, or there are multiple objectives need to be considered. Therefore, the constrained OCBA (Pujowidianto et al., 2009) or multi-objective OCBA (MOCBA) (Lee et al., 2004; Chen and Lee, 2010) will also be applied in this case.

2.3. Optimizer with MO-COMPASS / GO-POLARS

If there is a large set of candidate configurations, which is common when combinatory decisions are considered, it is not economical to enumerate all of them to evaluate even when OCBA is applied. Therefore, an optimizer embedded with large scale search algorithm can be utilized to deal with such a situation. In literature, MO-COMPASS (Lee et al., 2011; Li, 2013; Li et al., 2015a) is lately developed as a powerful tool for solving multi-objective simulation optimization problem, and GO-POLARS (Li et al., 2012; Li, 2013) is a way to improve search efficiency by utilizing gradient related information that can be probably abstracted from the simulation. Both techniques will be incorporated in the optimizer of the platform.

3. Preliminary Result and Roadmap

This study is still in progress and is planned for 6 months since December, 2015. So far we have developed the simulator based on O²DES framework. In the meanwhile, a simple desktop based interface (as shown in Figure 4) has been designed and integrated with the simulator for testing.

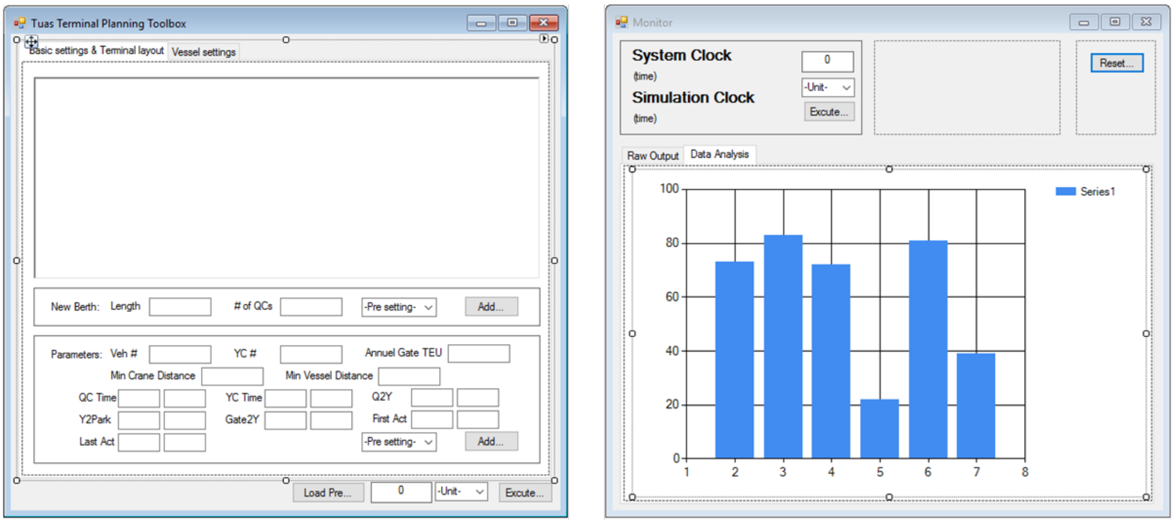

Figure 4: Example of the platform interface (Left is the setting panel and right is the output panel)

Next, different designs will be proposed and tested to achieve specific KPIs set by the decision makers such as berth on arrival, annual container rate, etc. Eventually, a complete platform will be presented.

References

Chen, C.-H. (1995). An effective approach to smartly allocate computing budget for discrete event simulation. In *Decision and Control, 1995., Proceedings of the 34th IEEE Conference on*, volume 3, pages 2598–2603. IEEE.

Chen, C.-H. and Lee, L. H. (2010). Stochastic simulation optimization: an optimal computing budget allocation, volume 1. World scientific.

Chen, C.-H., Yu¨cesan, E., Dai, L., and Chen, H.-C. (2009). Optimal budget allocation for discrete-event simulation experiments. *IIE Transactions*, **42**(1):60–70.

Lee, L. H., Chew, E. P., and Li, H. (2011). Multi-objective compass for discrete optimization via simulation. In *Simulation Conference (WSC), Proceedings of the 2011 Winter*, pages 4065–4074. IEEE.

Lee, L. H., Chew, E. P., Teng, S., and Goldsman, D. (2004). Optimal computing budget allocation for multi-objective simulation models. In *Simulation Conference, 2004. Proceedings of the 2004 Winter*, volume 1. IEEE.

Li, H. (2013). Stochastic search methodologies for multi-objective simulation optimization. PhD thesis.

Li, H., Lee, L. H., and Chew, E. P. (2012). Optimization via gradient oriented polar random search. In *Proceedings of the Winter Simulation Conference*, page 19. Winter Simulation Conference.

Li, H., Lee, L. H., Chew, E. P., and Lendermann, P. (2015a). Mo-compass: A fast convergent search algorithm for multi-objective discrete optimization via simulation. *IIE Transactions*, **47**(11):1153–1169.

Li, H., Zhu, Y., Pedrielli, G., Pujowidianto, N. A., and Chen, Y. (2015b). The object-oriented discrete event simulation modeling: A case study on aircraft spare part management. In *Simulation Conference (WSC), Proceedings of the 2015 Winter*. IEEE.

Pujowidianto, N. A., Lee, L. H., Chen, C.-H., and Yap, C. M. (2009). Optimal computing budget allocation for constrained optimization. In *Simulation Conference (WSC), Proceedings of the 2009 Winter*, pages 584–589. IEEE.

13:30 – 15:30	Session 4B (Floor 16)	Chair: Qiang Meng
	Theme: Maritime (Liner shipping and freight rate)	

Containership Deployment on a Liner Service
Shuaian Wang, Zhiyuan Liu, Xiaobo Qu and Lu Zhen and Hongtao Hu

Multivariate Modelling of Regional Ocean Freight Rates
Roar Adland, Steen Koekebakker and Fred Espen Benth

Will Liner Ships Make Fewer Port Calls Per Route?
Judith Mulder and Rommert Dekker

Resource Sharing Coordination for Carrier Alliances
Zhou Xu, Xiaofan Lai and Liming Liu

Containership deployment on a liner service

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1. Introduction

Liner shipping companies transport containerized cargoes on regularly scheduled services with fixed port rotations. The regular and reliable liner services make it possible for shippers (consigners or consignees) to arrange their production plans, manage their inventories, and arrange the delivery of final products. From shipping lines' viewpoint, the capacities of the shipping services are fixed, at least in short terms. Hence, shipping lines try to attract as many cargoes as possible to fill up the slots on the ships.

Uncertainties in container shipment demand are one of the major challenges for planning and operating liner services. At the tactical level, the services must be determined before the future demand is revealed. At the operational level, the number of containers available for loading in a week from a shipper may be different from what she has committed to. There are a number of reasons for this. For example, the shipper's production line is down and not enough products are assembled; or the shipper just changes her mind due to the changes in business environment.

To fill up ship slots, shipping lines adopt the strategy of overbooking. Similar to the airline industry, one rationale behind the practice of overbooking is the possible cancelations of reserved slots. Different from the airline industry, another rationale for shipping lines to overbook the capacities of the ships is that they can postpone the transportation of the containers. With very few exceptions, shipping lines almost never guarantee the date of delivery for containers. This makes it possible for shipping lines to accept more containers: if the number of containers available at a port is higher than the ship capacity, some of them will be transported in the next week. When the shipping market is down and hence shipping lines worry that they may not have enough demand in the next week, they tend to accept whatever shipping orders received. When shippers' containers are stacked in the container yard of an export port because the ship that visits the port in that week is full, shippers will not be compensated explicitly. Nevertheless, shipping lines do incur intangible costs, e.g., loss of goodwill, because of the inferior services provided for the shippers. In addition, more yard space is required to storage the delayed containers.

Deploying larger ships will reduce the average delay of containers under uncertain demand. However, larger ships have higher operating and voyage costs. Another possible approach, which is almost costless, is to optimize the sequence of ships in the string. Suppose that six ships are deployed on a trans-Pacific service, the capacity of ships 1, 2, and 3 being 8,000 twenty-foot equivalent units (TEUs) and the capacity of ships 4, 5, and 6 being 8,200 TEUs. Since the demand is random and may exceed 8,000 or even 8,200 TEUs in some weeks, some containers that are available for loading in a week will have to wait for the ship that comes in the next week. Intuitively, the sequence of the string of ships 1-4-2-5-3-6 should outperform the string 1-2-3-4-5-6, as the capacity distribution of the former is more "uniform" and can thereby dissolve the now-and-then high demand more efficiently.

In reality, although shipping lines seek to deploy ships of similar sizes on a route to provide uniform shipping services in each week, the ships in a string may not necessarily have the same capacity in terms of the number of TEU slots. For example, Maersk Line and MSC jointly operate an Asia-to-the-US West Coast service - Transpacific 2 (TP2) with the port rotation Kaohsiung, Hong Kong, Xiamen, Shanghai, Ningbo, Long Beach, and back to Kaohsiung again. Six ships are deployed to provide a weekly service and the difference between the capacities of two ships can be as large as 22.5%.

We identify the following two reasons that explain the ship size difference in a string: (i) Even if the string of ships was homogeneous, one of them may be under maintenance or repair, and hence another ship that may be different from the ones in the string has to come as a replacement. (ii) The rotation time of the route that the old string of ships needs to serve is changed, and new ships must be added to the string or some ships from the string have to serve other routes. For instance, when a string of mega-ships is delivered to replace an existing string on an Asia-Europe service, the latter string may be redeployed to an intra-Asia service due to the cascading effect. Some ships in the string will no long be needed as the intra-Asia service is shorter than the Asia-Europe one. A second example is service redesign due to business considerations, e.g., the pending expansion of the Panama Canal will enable post-Panama ships to visit the East Coast of the US from Asia via the Pacific Ocean. A third example is slow-steaming for saving bunker costs, which requires the insertion of one or two ships to an existing string.

2. Objectives

This paper investigates how to determine the optimal sequence of ships in a string to minimize the expected number of delayed containers taking uncertain demand into consideration. We use the phrases "sequence of ships", "string" and "permutation" interchangeably. The main challenge for the problem is that it is almost impossible to predict the probability distribution functions for the future demand. In fact, even if we have the historical data on the demand, the data may be of limited value because the shipping environment changes rapidly. Therefore, a good string should be robust in that it is optimal or near-optimal for any random demand.

3. Results and conclusions

We address a practical research problem that is of significant importance for shipping lines. We develop a model for calculating the delay of containers given a sequence of ships, and derive bounds for the best and worst sequences. We identify rules for choosing a good string that is optimal or near-optimal among all possible permutations, without requiring the probability distribution functions of the random demand. The chosen string by the rules is demonstrated to be near-optimal for very general distribution functions of the random demand based on extensive numerical experiments.

Multivariate modelling of regional ocean freight rates

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1. Introduction

Due to the mobility of ships, regional freight rates tend cannot diverge for long periods of time. If they did, rational profit maximizing shipowners would relocate tonnage to high-paying areas and adjust supply such that any excess regional profit disappears. However, such relocation necessarily takes time and so we may see short-run deviations from a common stochastic trend ('the market'). If such deviations are persistent enough there may be scope for optimizing ship operations (routing) to take advantage of any spatial inefficiency. The co-integrated nature of regional spot freight rates is clearly shown in Figure 1 below, which refers to four regional freight rates in the spot market for mid-size drybulk vessels (Supramax size, approximately 52,000 DWT) on the trans-Atlantic, trans-Pacific, fronthaul (Atl. to Pac.), backhaul (Pac to Atl.) routes.

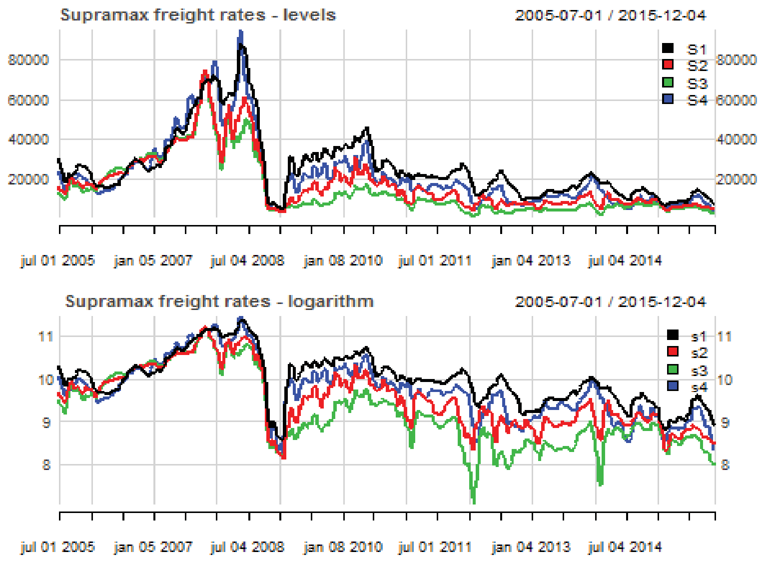

Figure 1: Regional Supramax freight rates

The aim of this study is to develop a new multivariate framework for the modelling and simulation of regional freight rates for ocean transport. We contribute to the literature by decomposing the observed regional spot freight rates into two additive processes – a common univariate 'market factor' and separate but correlated univariate 'regional factors'. This greatly simplifies the estimation and simulation compared to multivariate alternatives such as Vector Error Correction models (VECM).

3. Methodology

Let S_i represent the freight rate for route i. In a freight market with p regional freight rates the geometric average of the regional freights rate is given by

$$X(t) = \left(\prod_{i=1}^{p} S_i(t)\right)^{1/p}. \tag{1}$$

Setting x(t) = ln X(t) and $s_i(t)$ = ln $S_i(t)$ we have the following relationship

$$x(t) = \frac{1}{p}\sum_{i=1}^{p} s_i(t) \tag{2}$$

We assume that the logarithm of each regional freight rate consists of the common market factor, x(t), and a regional factor $y_i(t)$. The market factor and the regional freight rates are all observable at time t. This means that the regional factors are also observable at time t as the residual given by:

$$y_i(t) = s_i(t) - x(t) \tag{3}$$

We can model the market factor and regional factors as separate (correlated) univariate processes, and this simplifies the estimation and simulation considerably. We can proceed with our modelling in a stepwise manner: (i) compute the market factor and the regional factors, (ii) estimate a univariate model for the market factor and (iii) estimate a univariate model for each regional factor. The error terms driving each process can be correlated.

We assume that both the the market factor, and each of the regional factors, can be modelled as univariate AutoRegressive Integrated Moving Average (ARIMA) processes. In general, a time series z(t) with stationary ARMA(p, q)-dynamics is given by:

$$z(t) = c + \phi_1 z(t) + \ldots + \phi_p z(t-p) + \ldots + \theta_1 e(t-1) + \ldots + \theta_q e(t-q) + e(t) \tag{4}$$

with p autoregressive terms, q moving average terms and where e(t) represents the error term. The properties of a stationary time series do not depend on the time at which the series is observed. So time series with stochastic trends or seasonality, are not stationary. In our case the common market factor is expectedly non-stationary, while the regional factors (effectively a difference between two log-freight rate series) should be stationary. This is confirmed by formal unit root tests.

3. Results

We use weekly spot freight rate data from the Supramax segment in the period 2007-2015, N=540 observations for each route. We focus on the routes given in the table below.

Name	Route description
S_1	BSI Route S1: NWE/Black Sea to Japan-SK
S_2	BSI Route S2: Japan-SK/NOPAC or Australia RV $/Day
S_3	BSI Route S3: Japan-SK Trip Gib-Skaw range $/Day
S_4	SI Route S4: Transatlantic RV

The most appropriate specification for all the regional factors end up as ARIMA (2,0,0), except for route 2 which is an ARIMA (2,0,2) process. Correspondingly, the market factor x(t) can be ends up as an ARIMA(1,1,1)-process.

The descriptive statistics for the estimated residuals is provided in Table 1 below, followed by the correlation matrix in Table 2.

	$e_x(t)$	$e_{y_1}(t)$	$e_{y_2}(t)$	$e_{y_3}(t)$	$e_{y_4}(t)$
Mean	-0.001	0.000	0.000	0.000	0.000
Standard deviation	0.054	0.038	0.035	0.040	0.039
Skewness	0.545	-0.493	0.316	0.299	0.135
Excess kurtosis	6.752	5.283	5.006	8.476	1.860

Table 1: Descriptive statistics for estimated residuals

	$e_x(t)$	$e_{y_1}(t)$	$e_{y_2}(t)$	$e_{y_3}(t)$	$e_{y_4}(t)$
$e_x(t)$	1.00	-0.59	0.40	0.34	-0.16
$e_{y_1}(t)$	-0.59	1.00	-0.65	-0.67	0.32
$e_{y_2}(t)$	0.40	-0.65	1.00	0.36	-0.65
$e_{y_3}(t)$	0.34	-0.67	0.36	1.00	-0.70
$e_{y_4}(t)$	-0.16	0.32	-0.65	-0.70	1.00

Table 2: Correlation matrix for estimated residuals

We further build a simulation engine for the regional freight rates. Here the data analysis and modelling process is reversed. We proceed in three steps

1. Draw correlated random error terms for e_x (t) and e_i (t)
2. Simulate univariate ARIMA(p,d,q) models for x(t) and y_i (t)
3. Compute the regional spot freight rate as S_i (t)=exp(x(t)+y_i (t))

In the table below we simulate random draws for the market factor and each of the routes. We draw from the multivariate normal distribution with zero means, and covariance matrix from the estimated residuals above. The correlation matrix for the simulated error terms are given in the table below. We see that the correlation matrix for the simulated residuals, closely match those of the estimated residuals. We also present descriptive statistics for the simulated errors. As expected when using the normal distribution, we are unable to capture the fat tails in the real underlying process.

	$e_x(t)$	$e_{y_1}(t)$	$e_{y_2}(t)$	$e_{y_3}(t)$	$e_{y_4}(t)$
Mean	0.00	0.00	0.00	0.00	0.00
Standard deviation	0.05	0.04	0.04	0.04	0.04
Skewness	-0.03	-0.03	0.01	0.01	0.02
Excess kurtosis	-0.11	0.04	0.01	-0.02	0.05

Table 3: Descriptive statistics for multivariate normally distributed errors

4. Concluding remarks

We have developed a new and parsimonious model for the decomposition of a multivariate regional freight rate process into a univariate common market factor and separate but correlated univariate regional factors. Moreover, our empirical estimates show that the dynamics of the common and regional factors conform to economic intuition by being non-stationary and stationary, respectively.

Further refinements of this model should investigate the use of more complex distributions, such as the multivariate NIG distribution, to better capture the fat tails of the empirical data.

Will liner ships make fewer port calls per route?

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1 Background

The growth in container trade has led to substantial increases in container ship sizes. Larger ships are well-known to benefit from economies of scale at sea, but they may suffer diseconomies of scale in ports. In [1] a study is performed to investigate the (dis)economies of scale in large container ships both in port and at sea. They considered container ships varying in capacity from 200 to 8,000 TEU. Their findings show that diseconomies in ports exist for ships larger than 1,500 TEU, but that the magnitude is quite small. Furthermore, they show that economies of scale at sea exists at least for ships up to 8,000 TEU and the economies of scale at sea clearly outweigh the diseconomies of scale in ports.
The increase in container ship size also has its consequences on the network structure in liner shipping. Not all ports are capable of handling large-size container ships. Furthermore, it might not be profitable to call at relatively low-demand ports with large-size container ships. Therefore, traditional liner networks containing so-called simple and butterfly routes may shift to more hub-and-spoke like networks. In simple routes, ports are all visited exactly once on each rotation, while in butterfly routes ports are allowed to be called twice during a rotation. Hub-and-spoke networks consist of a small number of large hub ports, which are connected with each other. All other (smaller) ports in the networks are called spokes or feeder ports and are only visited on routes originating from and destined for their closest hub. In South America, shipping routes are recently reconstructed towards networks similar to hub-and-spoke networks. Furthermore, direct services between regions with high demand are introduced [2].
Call sizes at terminals have increased as well, as a consequence of the total growth in container trade. This poses problems for terminals, as they face a larger peak load for the stack. Yet larger call sizes on bigger ships also benefits terminal quay crane productivity as cranes can work longer on a bay.
All in all, this raises the question whether container ships should reduce the number of port visits on a string in order for terminals to be more productive and reduce unproductive port time. In this research, we will investigate whether a shuttle service between two ports is to be anticipated.

2 Solution methodology and results

A small number of large ports are identified in the dataset and used as hub ports in the network. In order to keep the main network simple, at most one hub port per demand region is chosen. Shuttle services between these hub ports are added to the service network. Cargo demand from and to other ports in the network is delivered via these hubs only. In this way we have made sure that we have a hub-and-spoke system. Each port in the dataset is allocated to its closest hub port. Then, for each hub port all these ports are clustered into one or more clusters. Clustering is based on geographical location, total cargo movements and draft restrictions. Then, for each cluster a travelling salesman problem is solved to obtain initial feeder routes.

After the initial network is fixed, a mixed integer programming problem is formulated to find the optimal allocation of ships, sailing speed and frequency and cargo routing over the service network. Binary variables are used to determine whether a route is used and which ship type, sailing speed and sailing frequency is used on the route. The cargo flow is modelled using continuos variables which indicate the flow over different paths in the network.

The mixed integer programming problem is used to determine the profit of the initial network. Using the cargo flow over this network, the feeder routes can be improved. Using the amount of transported containers of the mixed integer programming model, the currently satisfied demand and supply of each feeder port can be found. For each cluster the new feeder routes are found by enumerating all possible routes and selecting the most profitable ones under the condition that the currently satisfied demand and supply are still transported in the new feeder network. In this way, a new service network is constructed and the profit can again be determined by solving the MIP problem.

The solution methodology described above is applied to the Asia-Europe network of the benchmark suite as described in [3]. This dataset is based on data provided by Maersk Line. 7 hubs are identified as hub ports in the network: Bremerhaven, Rotterdam, Algeciras, Jebel Ali, Tanjung Pelepas, Shenzhen and Shanghai. Rotterdam and Bremerhaven are large ports in Europe, while Shenzhen and Shanghai are large ports in Asia. Tanjung Pelepas the port close to Singapore that Maersk Line mainly uses for its port call in the Singapore region. Also, Algeciras (located in the most southern part of Spain) turns out to be an important transhipment port. The networks constructed using these networks perform more than 25% better than the current best networks in literature based on the benchmark dataset, which provides an indication that services with fewer port calls might be profitable to include in liner shipping service networks.

References

[1] K. Cullinane and M. Khanna (1999), Economies of Scale in Large Container Ships, *Journal of Transport Economics and Policy* 33, 185-207.

[2] R.J. Sanchez and G. Wilmsmeier (2011), Liner Shipping Networks and Market Concentration, *International Handbook of Maritime Economics*, K. Cullinane (ed), 162-206, Cheltenham, U.K.

[3] B.D. Brouer, J.F. Alvarez, C.E.M. Plum, D. Pisinger, M.M. Sigurd (2014), A Base Integer Programming Model and Benchmark Suite for Liner-Shipping Network Design, *Transportation Science* 48, 281-312.

Resource Sharing Coordination for Carrier Alliances
(Extended Abstract)

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Abstract

In this paper, we consider resource sharing in liner shipping, where carriers, when providing shipping services, collaboratively share their resources, such as vessel capacities and empty containers, so as to maximize their overall profits. We propose a novel sharing mechanism that can not only guarantee stable collaboration among carriers, but can also ensure a decentralized implementation of the centrally optimal resource allocations. Our sharing mechanism is valid for all behavioral models known in the literature that individual carriers may choose to adopt. Results from this study have also provided several new and interesting insights into resource sharing and its coordination.

Keywords: resource sharing, liner shipping, carrier alliance, cooperative game, mechanism design

1. Introduction

In this paper, we consider a general resource sharing problem in a carrier alliance, where the carriers collaboratively use their idle resources, such as vessel capacities and empty containers. The problem is motivated by the recent trend where more and more carriers form an alliance to share resources for maximizing their profits. For example, carriers Maersk and Mediterranean have, since 2014, formed a "2M" alliance to share vessel and shipping capacities. However, each of the two carriers in "2M" makes their own independent decisions on practical operations, and optimizes their own objectives. Therefore, due to the decentralized nature of carriers' operations, it is hard for alliance policy makers to coordinate the carriers and to devise a profit allocation scheme that can maintain the stability of the alliance. This study aims to resolve these issues and to provide effective mechanisms such that the decentralized carriers have incentives to collaborate and coordinate for sharing so as to attain an overall optimal profit for the alliance.

In the literature, there are some studies that have considered issues with regard to capacity sharing among liner shipping carriers. For example, Agarwal et al. (2010) proposed a network design and profit allocation mechanism to coordinate carriers that make network design and cargo routing decisions in a decentralized manner. Their mechanism considers each carrier's behavior through a conservative model, in which each individual carrier can also make decisions on other carriers' cargo flows and vessel capacities. Under such a behavioral model, they used side payments to provide incentives to carriers for sharing resources, and applied an inverse optimization technique (Ahuja, 2001) to show the existence of such side payments. However, their profit allocation mechanism may not always be in the core, which indicates that sub-coalitions among some carriers can be formed.

Later, both Houghtalen et al. (2011) and Gui et al. (2013) considered a special case of the problem studied by Agarwal et al. (2010), and they used a similar approach to study the coordination of vessel capacity sharing. More recently, Zheng et al. (2015) extended the work of Agarwal et al. (2010) by considering variable container demands by the carriers, and they also followed a similar approach to studying its coordination. It can be seen that the above existing literatures on the coordination of capacity sharing focus only on restricted optimization models for certain specific applications. Moreover, their solution approaches are based mainly on inverse optimization, which is complicated and hard to be generalized.

These issues in actual practice, together with the limitations in the literature, have motivated us to consider resource sharing in a general form, since a general mechanism for coordination is greatly needed. The contribution of this paper is threefold: Firstly, we have introduced a more general model, as well as a mechanism for coordination, for the resource sharing problem, such that the results obtained are more general and have wider applications; secondly, a general behavioral model and a general method has been proposed to derive the price for coordination, which greatly simplifies the analysis for resource sharing; finally, we have further extended our new approach to wide, complex, but more realistic applications, including those with uncertainty factors and those with integer decision variables. The results from these applications provide even more useful insights for improvements in practice.

2. Coordination Mechanism for Resource Sharing

Consider a set of carriers in liner shipping who always gain their profit through making use of their resources, such as demand and capacity. Each carrier, when optimizing individually, needs to maximize its own profit and make its own decisions on how to arrange its own resources. However, it may be that carriers always have some idle resources. To maximally exploit these resources, carriers often form an alliance so as to further improve their profit. In this case, there are two particular types of decisions that must be considered: one is to decide on the resource allocation, and the other is how to utilize the resource. Therefore, we propose a general joint model that aims to consider resource sharing in an alliance setting. The model has a concave objective function that is to maximize the total profit. Its constraints include those representing how to allocate the aggregated resource and how to use the resource for each carrier to create profit, as well as those representing a balance of cargo flows.

After forming an alliance, the carriers jointly optimize their operations so that their overall profit can be improved. The improved profit therefore needs to be allocated among the carriers. We impose a linear price on each type of resource, such that the profit can be allocated to each carrier by a side payment method that is based on this linear price and the amount of resource used. This profit allocation method is natural and realistic for practical usage.

To coordinate the decentralized carriers, we propose a sharing mechanism that relies on a trusted third party, which could be a common internet-based platform, or the headquarters of a global company. The mechanism includes the following two steps:

1. Collect information from each individual, and solve the joint model for resource sharing;
2. Allocate profit to individuals through revealing certain centralized decision information, such as the resource price and the resource allocation plan.

As we will show in the following section, the profit allocation obtained by the above mechanism can not only guarantee stability of the alliance, but can also provide sufficient incentive for motivating the decentralized carriers to implement this mechanism.

3. Incentives for Coordination

To investigate the stability of the alliance, we define a cooperative game based on the above joint model for resource sharing, and we use the "core" concept in cooperative game theory to ensure that any individual carrier or subset of carriers have no incentives to deviate from the grand coalition.

Moreover, to further provide incentives for each carrier to implement the central optimal resource allocation, we take the decentralized behavior of each carrier into account, and propose a general behavioral model to characterize the decision behavior and strategy for each carrier. These behavioral models determine the minimum profit that each individual expects to achieve. Hence, such individuals will only accept an allocation plan that can obtain a profit allocation greater than this expected profit. Moreover, our general model can cover all existing behavioral models in the literature, including:

1. Conservative model: Each carrier can not only make its own decisions, but also those of other carriers. This model type can output the most conservative profit expectation.
2. Force constraint model: The trusted third party imposes a certain constraint on the resource usage in this model, and forces each individual to follow it.
3. Equilibrium-based model: Each individual carrier knows the decisions of other carriers when making its own decisions.
4. Trade-based model: Each individual obtains resource price information from the trusted third party, and the resource is traded using this price.

Furthermore, we can show that our mechanism is robust to the carriers' behavior models. No matter which behavior model each carrier follows, the mechanism guarantees no incentive for carriers to form sub coalitions, and guarantees to achieve profits no less than their expectations.

4. Conclusions

Our study has provided a general sharing mechanism such that the final profit allocation can not only guarantee stable collaboration among carriers, but can also ensure a decentralized implementation of the centrally optimal resource allocation. When considering the incentives for cooperation, we have generalized the behavioral models in the literature and also provided a general model. By taking into account the relationships between the different types of models, we have provided a general method of obtaining a price for cooperation, no matter which behavioral model the carriers adopt. Moreover, when applied to a linear case, our method is much simpler than the existing inverse optimization approach.

In addition, our result and method can be further extended to more general settings, such as for problems that include uncertainty or integral decision variables. It can also be applied to applications other than liner shipping, such as those for airline alliance and inventory sharing. This study has revealed several new managerial insights into resource sharing and its coordination.

References

R Agarwal and O Ergun (2010) Network design and allocation mechanisms for carrier alliances in liner shipping, *Operations Research*, **58**(6):1726–1742.

R Ahuja and J Orlin (2001) Inverse optimization. *Operations Research*, **49**(5):771–783.

L Gui and O Ergun (2013) Managing decentralized resource sharing in multicommodity networks, *Working Paper*.

L Houghtalen, O Ergun, and J Sokol (2011) Designing mechanisms for the management of carrier alliances. *Transportation Science*, **45**(4):465–482.

J Zheng, Z Gao, D Yang, and Z Sun (2015) Network design and capacity exchange for liner alliances with fixed and variable container demands. *Transportation Science*, **49**(4):886-899.

16:00 – 18:00	Session 5A (Floor 17)	Chair: Stein W. Wallace
	Theme: Logistics (Network designs and transport operations)	

A Coalitional Game-Theoretical Approach to the Design of Express Delivery Service Network Based on Strategic Alliance
Youngjun Ko, Friska Natalia Ferdinand and Chang Seong Ko

Network Design and Transport Operation by Assigning Cargo Aircrafts and Time-Space Network
Shunan Yu and Zhongzhen Yang and Kang Chen

Hybrid Strategies for Order Picking in a Warehouse for Fashion E-Commerce
Giulia Pedrielli, Vinsensius Albert, Ek Peng Chew and Loo Hay Lee

Construction of a Comprehensive Analysis Foundation for an Optimal Nodes Placement
Shinya Mizuno, Yoshikazu Fujisawa and Naokazu Yamaki

A coalitional game-theoretic approach to the design of express delivery service network based on strategic alliance

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1. Introduction

Express delivery service is nowadays considered as one of the most efficient delivery methods due to far-flung nature of business operations in the global economy, with the active use of e-commerce, TV home shopping, and door-to-door deliveries. In particular, the total Korean market size of delivery service industry is expected to reach up around 2 billion in quantity by 2016, with over 10 percent of annual growth rate since 2001(Chung et al. 2009).
Nevertheless, most of express delivery service companies are making their efforts to increase their delivery amounts with rapid and on-time delivery within a well-built infrastructure. However, some of express delivery service companies in small and medium sizes are suffering from competition for low prices, difficult acquisition of delivery vehicles, and lacking country-wide terminals. As a remedy, alliance enables small and medium sized companies to expect reduction of operational cost by eliminating overlapped investments. In addition, through efficient cooperation of service centers, participating companies look forward to net profit increase under a win-win situation (Ferdinand et al. 2013).
Last decade, several studies were performed in the field of express delivery service network design reflecting strategic alliance (Chung et al. 2009, 2010, 2011; Ferdinand et al. 2012, 2013). Also, Ferdinand et al. (2014) took account of collaborative pick-up and delivery routing problem of line-haul vehicles as figures to maximize the incremental profits of collaborating companies.

This study suggests a sustainable alliance model to increase the competiveness of each participating company with monopoly of service centers and equitable allocation of alliance profits. A co-evolutionary genetic algorithm based heuristic is developed for network design, which can work out under a distributed decision-making scenario assumed in collaboration system.

2. Problem Definition

This study is divided into two sub-problems: first, this study suggests a compromised network design model which describes modes to facilitate strategic alliances among small and medium-sized companies in delivery service industry. The objective of the proposed model is to show how to increase the net profit of each allied company by harnessing their under-utilized service centers with low demand and sharing consolidation terminals with available processing capacities; second, this study determines how to allocate coalition profits to the companies respectively.
In regions with low demands, the participating companies can bargain to form an alliance through monopoly of service centers. The collaboration works out in strategic alliance as follows:

a) In most candidate merging regions, only a single service center can be open. However, the possibility of survival of multiple service centers lies ahead in some merging regions and as a result, all the other service centers will be closed within this merging area after collaboration.
b) The survived service centers after alliance are also responsible for all the amounts of pick-up and delivery of other company's service centers within the same merging region.

c) Each company’s service centers are divided into two types: Service centers in a merging region are defined as Type I, and service centers that do not belong to any merging regions are defined as Type II.
d) Both open service centers in each merging region and Type II service centers can be reallocated to other company’s consolidation terminal, satisfying the processing capacity of terminal simultaneously.
e) Each company should fulfill the processing capacity of the terminal after alliance.

Next, this study establishes a systematic methodology to form a coalition in express delivery services by equally allocating its profits to every participating company regarding their contribution. The Shapley value allocation methodology is also applied to estimate the contribution of each company in the alliance (Shapley 1953, Tarashev et al. 2009).

3. Model design

This section describes the nonlinear integer programming model to maximize the expected profit increase of each participating company. Suppose that there are n express courier companies, and that the location of terminals and service centers that had been managed by each company is given. The underlying premise is that in m regions, all n companies possess one service center independently with comparatively small amount of shipment. In addition, the daily pick-up amount for the service centers in each region and the processing capacity of terminals per day are given. Under these conditions, the problem is to maximize the profit of each company by selecting single or multiple service centers among candidated service centers within each region and to reallocate the open Type I and Type II service centers to terminals, considering the processing capacity of all the terminals. It is also possible that all terminals operated by one company can be available to other companies after alliance.

4. Conclusions

As the market size of express courier industry is growing in a rapid pace, more severe competition among express courier companies is rising to the surface. The adoption of strategic alliance may be an adequate way to enhance their competitiveness because it has many meaningful advantages. Through an efficient sharing of service centers and/or consolidation terminals, all the allied companies may experience an increase in net profits. In this study, we presented a network design model for strategic alliance among small and medium sized express courier service companies. Also, a systematic methodology was proposed for equitable allocation of coalition profit to each company according to its marginal contribution. Other problems in strategic alliance, such as closedown of existing terminals and capacity change of terminals, are to be included in the future research.

Acknowledgement

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References

K H Chung, J J Rho and C S Ko (2009) Strategic alliance model with regional monopoly of service centers in express courier services, *International Journal of Service and Operation Management,* **5**(6), 774-786.

K H Chung, C S Ko, Y M Hwang and J J Rho (2010) Network design for strategic alliance in express courier services: a fuzzy set approach, *International Journal of Innovative Computing, Information and Control*, **6**(1), 349-359.

K H Chung, H J Ko, F N Ferdinand and C S Ko (2011) A fuzzy set-theoretic approach to the weak strategic alliance for the survival of multiple service centers in express courier services, *ICIC Express Letters: International Journal of Research and Surveys,* **5**(2), 385-389.

F N Ferdinand, K H Chung, H J Ko and C S Ko (2012) A compromised decision making model for implementing a strategic alliance in express courier services, *INFORMATION: An International Interdisciplinary Journal*, **15**(12c), 6173-6188.

F N Ferdinand, I K Moon, K H Chung and C S Ko (2013) A decision making model for strategic alliance-based network design in express delivery services, *ICIC Express Letters: International Journal of Research and Surveys,* **7**(6), 1813-1818.

F N Ferdinand, Y J Kim, H K Lee and C S Ko (2014) A study on collaborative pick-up and delivery routing problem of line-haul vehicles in express delivery services, *International Journal of Industrial Engineering,* **21**(6), 376-383..

L Shapley (1953) A value for n-person games, *Annals of Mathematical Studies,* **28**, 307-317

N Tarashev, C Borio and K Tsatsaronis (2009). The systemic importance of financial institutions, *BIS Quarterly Review*, 75-87.

NETWORK DESIGN AND TRANSPORT OPERATION BY ASSIGNING CARGO AIRCRAFTS AND TIME-SPACE NETWORK

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Abstract: High timeliness is one of the merits of express transport, which holds the key role of the service level and greatly affects the competitiveness of the service companies. Thus, to satisfy the timeliness, air express companies should raise the speed and efficiency for the parcel collection, transport and delivery. In present China, the operation mode of “first arrive first serve” is generally adopt by the air express companies to handle the express parcels. The air express companies serve the arriving parcels immediately with the nearest transport capacity to let the parcels reach the destination as soon as possible.

However, this operation mode despises the reasonable matching between the service and the demand and neglects the fact that the timeliness of express parcels has a tolerance. Thus, the transport scheme may be good and reasonable in micro level, while in macro level the transport capacity may not be used well or the total transport time of all parcels may not be minimized in a tolerated period. As most shippers only request their parcels to be transported to the destination in a certain periods of time rather than in fastest speed, “FAFS” mode for each parcel may not be the optimal operation strategy. It is necessary for air express companies to optimize the handling scheme based on the demand, the supply and some other factors in each time period under the condition of meeting the timeliness.

In the case of the express parcels being able to be sent out in the same day with their arrival, this paper adds cargo aircraft links to the belly network of passenger aircrafts and then optimizes the transport scheme for all the parcels on the network. It is a problem of discrete network design and transport operation. To solve the problem, we construct a bi-level programming model. In the upper model, the cargo aircrafts are assigned to links with the objective to minimize the total transport cost. In the lower model, parcels flows on links in each time period are calculated from parcel OD flows with the principle of system optimization (SO). For the upper model, a genetic algorithm is designed to find the solutions. For the lower model, first we expand the network consisting of city nodes, airport nodes and links with flight frequencies into a time-space network. And then we change the daily total parcel OD flows between cities into parcel OD flows between nodes in the network based on the ratios of each time period. Data of 14 cities that are served by SF Air Express Company in China are used to do the case study. Through the results of the upper model, the reasonability of the hub airports and cargo aircrafts' routes is discussed. With the results of the lower model, we analyze the situations of the waiting and travel of the parcels. At last, the sensitivity of timeliness tolerance on the results is carried out. It is found that total transport cost decreases with the timeliness tolerance while the total transport time increases with the timeliness tolerance.

Keywords: Air express parcel transport scheme; bi-level model; time-space network;

Hybrid strategies for order picking in a warehouse for fashion e-commerce

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1. Background and Motivation

E-commerce has become an increasingly relevant business in South East Asia and particularly in Singapore. This research is motivated by the collaboration with one of the main fashion e-commerce companies in Singapore and South East Asia region. As in other businesses, the effective management of the warehouse in terms of supply, location and picking represent key competitive advantages for a company competing in this industry.

Fashion products have distinctive characteristics which make them particularly difficult to efficiently manage in a warehouse; this is even more apparent in the case of low-value fashion products. More specifically, in the case of fashion products we have high variability in the demand in terms of volumes and value, short shelf life and rare replenishment of products where items are usually replaced with new collections.

As a result of these characteristics, warehouse management becomes highly complicated due to the difficulty in recognizing highly frequent (stable) items and therefore organize the put-away (i.e., the inventory location) as well as the generation of the picking lists for the pickers.

In such a volatile environment, a single unique picking strategy is unlikely to satisfy the very diverse order profiles characterizing the demand faced by such an e-commerce company.

In this work, starting with a detailed demand analysis and the physical layout of the warehouse, we propose: (1) fast algorithm for generating picklists which consider several aspects such as work balancing and picking time minimization, (2) a family of picking strategies which takes into account the possible order configurations as well as the layout of the current warehouse. In order to assess the performance of the different strategies we propose the use of simulation as a general approach which can be easily extended to more complicated layouts.

2. Warehouse Operations: a review

Warehouse operation management has been a topic of attention for a considerable time and it is still a relevant research area (Xie et al. 2015; Grosse et al. 2015). Nevertheless, current research mainly refers to fairly stable demand profiles which is not the case in the fashion e-commerce industry. However, the authors recognize that the concurrent implementation of multiple strategies might perform best with respect to the difficulty in identifying a single unique optimal strategy and this philosophy is aligned with this paper.

Gu et al. (2010) offer another overview of order picking strategies and identify the following phases which characterize the order picking process: batching, routing and sequencing and, finally, sorting. The batching problem is part of planning for order picking. Orders are received and subsequently released for fulfillment. Given a set of released orders, the problem is then to partition the set into batches, where each batch will be picked and accumulated for packing and shipping during a specific time window, or *pick wave*. Typically, the problem needs to be tackled by considering the picker effort, the load balance among pickers, the available time slots, the picker capacity and the due dates of the order. Therefore, a batching problem really solves two sequential problems: (1) generating the order waves and (2) within a single wave, assign the orders to the different pickers. As recognized by the authors, although the largest part of research has been in the area of assigning order to pickers, picking/storing location of an item are considered as given and the problem where there are several candidate locations for the retrieval or storage of an item is more complex and few research results are available, although it is often found in practice. In this paper, we consider the latter problem and we perform a choice of location in the effort of load balancing among pickers.

3. Methodology

In this work we assume that a layout of the warehouse exists (with inventory locations) and we have a list of orders available. We adopt the concept of *master-picklist* as the main output of the picklist generation procedure which we propose. Put simply, the master-picklist is the picking list generated for a single picker, where orders are sorted in terms of location (UID) assigned by Algorithm 1 which will be presented in section 3.1. The proposed process is:

1. Batch incoming orders;
2. Group orders in a batch according to three order types: (1) multi-item single zone, (2) multi-item multi zone, (3) single item;
3. If the picking strategy is not the base case, generate the order queues corresponding to the three order types;
4. Implement the picking process according to the strategy.

3.1 Pick List Generation

The policies will impact the generation of the queues and consequently, the generation of the picklists. In the following, we describe the picking process, by focusing on the phases of batching, order assignment and routing through queue and picklist generation.

Batch creation: receives as input the list of orders and generates the batches to be processed. Through simulation we plan to study the impact of the batch size on performance. Batch sizes are a function of the totes capacity, number of orders and system capacity. This first separation step of batching strongly depends on the system capacity – each batch contains 3 hours' worth of picking activities, although it is not clear how to generate them.

Queue Generation: receives as input the Master-Batch of orders, number of pickers, number of totes, capacity of totes and inventory snapshot (inventory locations). The output of this phase is the location (UID) to associate to the items in the Queue. Two main criteria are used to choose the UID: (1) "Queue dependency": given the inventory layout the items which are close (same floor, same zone, etc.) are put in the same queue and assigned the UID of the chosen area (zone, floor); (2) Order characteristic: is the order express (highest priority), single or multiple item; (3) "Virtual Backlog": while assigning items to queues, we need to consider that the UID has been virtually reserved and the inventory for the item at the specific location has to be updated accordingly. This will avoid multiple operators to be directed to the same, eventually empty, location.

Inventory Reservation Procedure: Once a zone with an item is identified, all the locations in the zone are sorted and while the first location UID is assigned the remaining possible locations are all eliminated. The reservation of the inventory is performed by decrementing the item availability at the selected UID.

Picklist Generation: receives as input the Picking Strategy, Queues generated, Number of operators, maximum size of the picklist. The output is the Master-picklist(s) for each picker with routing (items sequencing).

The queue contains the set of items which are then assigned to the pickers based on their capacity. The master pick list cuts the queue with the suggested UID with maximum availability based on the input information concerning the picker capacity.

Algorithm 1: Queue and Picklist generation algorithm

Queue Generation (Allocation)		
Location Map construction (Input Preparation)		
Type 1 orders generation	Create the list of multi-item single-zone orders. Each order reports all the possible fulfilment zones	$O1_m$ = [z1, z2, …] …. On_m = ….
Type 2 orders generation	Create the list of multi-item multi-zone orders. Each order is characterized by an array of pairs of the type (vector of zones, item).	$O1_{mm} = [(\mathbf{z}_1, I_1), \ldots]$ …. On_{mm} = ….
Type 3 orders generation	Find all the zones fulfilling single-item order	$O1_s$ = [z1, z2, …] …. On_s = ….
Picklist Generation (Assignment)		

Type 1 orders UID allocation	*For All Orders in Type 1 List*{
	While(not assigned && zones! empty){
	If (z_i in list is available)
	Inventory reservation procedure
	Assigned = true;
	Else eliminate z_i and $z_i \leftarrow z_{i+1}$ }
	If(zones==empty) Add to type 2 order and augment Type 2 Orders List
	}	

Type 2 orders UID allocation	*For All Orders in Type 2 List*{
	For All Items j in the order{
	Select the zone with the most number of items of the same order
	While(not assigned){
	If (available) **Inventory reservation procedure**
	Assigned=true
	Else go to alternative zones in the vector $z_i^j \leftarrow z_{i+1}^j$ }
	}}	

Type 3 orders UID allocation	*For All Orders in Type 3 List*{
	Choose the candidate zone with lowest load
	If (available) **Inventory reservation procedure**}	

3.2 Picking Strategies

For the picklist generation, we propose four different picking strategies which practically differ in the presence of a sorting station. The strategy A represents the reference baseline case which does not rely on any picklist generation algorithm and instead, processes orders sequentially in a FIFO manner.

Strategy A (Pure Order Picking). In this baseline strategy, we adopt the "Order-based Model" where orders are sent straight to picklist and sequentially processed without any type of order queue generation.

Strategy B (Hybrid Order Picking). This strategy uses the concept of master-picklist.

- Type 3 orders: Single Item orders are separated in special queues for fast processing;
- Type 1 orders: Multiple Item Orders belonging to same zone are grouped under selective queues. A master-picklist of predefined size (based on the capacity of the picker cart (or tote)) is generated indicating the suggested location along with the optimized picking path. The location assignment as well as the path generation are performed by Algorithm 1. Sorting of items happens on the cart and completed orders get sent to the warehouse outbound for packing.
- Type 2 orders: Orders across zones are grouped into a separate queue. They get partially picked in a zone and sent to the subsequent zone(s) till completion.

Strategy C (Hybrid Zone Picking). This strategy is a mix of Order Picking and Zone Picking:

- Type 3 orders: Single Item orders are separated in special queues for fast processing. Sorted by optimal path;
- Type 1 orders: Multiple Item Orders belonging to same zone are grouped under selective queues. A master-picklist of predefined size is generated indicating the suggested location along an optimized picking path as generated by Algorithm 1. Sorting of items happens on the cart and completed orders get sent to outbound.
- Type 2 orders: Multi-zone Orders are batched together in batches of predefined size. Items are dispersed in batches to be picked per zone. Batches get assigned to pickers allocated to each zone and picked into big totes. Completed totes get sent to collection area. Once all totes of one batch are received, the whole batch is pushed to the sorting station for consolidation.

Strategy D (Pure Zone Picking).

- Type 3 orders: Single items are picked in separate totes;
- Type 1 and Type 2 orders: All other orders are grouped in big batches and dispersed to all zones.
- Completed totes get sent to collection area. Once all totes of one batch are received, the whole batch is pushed to the sorting station for consolidation.

4. Preliminary Results and conclusions

In the following, we present some preliminary simulation results which compare the performance of the different picking strategies and order allocation rules. We highlight that the ultimate goal in this research is to explore whether multiple strategies can be concurrently implemented and study the related performance improvement.

The preliminary test case involves more than 5000 items in about 3000 orders representing a typical set of orders received in a day. Queues are generated based on the strategy for the individual type of order. The statistics of interest are presented in Table 1. From the results, we see that Strategies C and D are promising while the current Strategy A is outperformed mainly due to the abundance of single-item orders. The number of active pickers, and correspondingly totes in use, is highest for strategy A in terms of average and maximum. Moreover, since we have 150 pickers, we note that strategies C and D yield fewer number of picklists than number of pickers, resulting in some slack. In a future study, we may consider the impact of order sorting as required by Strategies C and D to evaluate if the trade-off is worthwhile.

Table 1: Simulation Results (Preliminary)

	Strategy A	Strategy B	Strategy C	Strategy D
Simulation run length	4 hr 11 min	4 hr 34 min	5 hr 22 min	5 hr 26 min
Average picking time (min/item)	4.81	4.72	4.63	4.62
Number of picklists (cumulative totes)				
Order-based	262	168	29	-
Item-based	-	20	88	103
Average load per tote (item/tote)				
Order-based (max 12 orders)	19.35	24.5	25.1	-
Item-based (max 50 items)	-	47.7	49.3	49.2
Number of active totes in use				
Average	96	87	72	71
Maximum	150	142	109	103

References

J Gu, M Goetschalckx, LF McGinnis (2010). Research on warehouse design and performance evaluation: A comprehensive review. European Journal of Operational Research, 203(3), 539-549.

J Xie, Y Mei, X Li, and A Song. (2015). A restricted neighbourhood tabu search for storage location assignment problem. In *Evolutionary Computation (CEC), 2015 IEEE Congress* on (pp. 2805-2812). IEEE.

EH, Grosse, C H, Glock, M Y, Jaber, and W P Neumann. (2015). Incorporating human factors in order picking planning models: framework and research opportunities. *International Journal of Production Research*, 53(3), 695-717.

Construction of a comprehensive analysis foundation for an optimal nodes placement

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1. Introduction

Recently, we need to arrange for optimal nodes placement in various situations. For example, social experiments have been conducted using rental bikes available at distribution nodes. When people borrow bikes, they return them at nearby nodes. This model expands into the automatic operation car called people mover as well as a bike. It takes much time for movement in an amusement park for a senior people. It's necessary to arrange suitable node arrangement to use people mover efficiently. We also have to arrange a shelter and a first-aid station efficiently in disaster.

However, many problems have been reported from these experiments. Moreover, it is costly to run these operations. The results of these experiments are obscured regarding the system construction, including the number of objects such as bikes, people movers and shelters, the nodes that should be used, and the placement of the nodes. Because the selection of parameters of a system depends on the person designing it, the resulting system may not be optimal.

In this paper, we propose a platform of a comprehensive analysis foundation for an optimal nodes placement. This platform consists of modelling, optimization and simulation. And we attempt to solve problems such as where to place nodes, how many nodes should be prepared, and how many objects should be available for each node for various model. We formulate a platform using the queueing network Miyazawa(1993), Miyazawa(2006), and this platform is calculated using mathematical analysis. Using our platform, we can easily visualize the settings of the system as they change with time. Our method for designing objects distribution systems does not depend on the country, the area or model being deployed. Moreover, we use Google Maps to obtain parameters, such as duration and distance between nodes.

2. The foundation outline and Modelling using closed queueing networks

We propose a platform of a comprehensive analysis foundation for an optimal nodes placement. This platform consists of modelling, optimization and simulation referred as figure 1. For optimizing placement for any model, we use closed queueing network to evaluate the congestion in system. Then we get the result from this closed queueing network. From this result, we optimize the number of nodes and objects, location of node. We consider the model using closed queueing network as a static model. To apply it to an actual model, we know better to simulate for this model. We confirm the validity of the parameter by a simulation. It is important to make a static model and simulation circulate.

Next we formulate a model using the queueing network.

i. the type of customer using the network services in the network,

ii. K sites within the network, and

iii. that the system would have a finite number of total customers (N), to satisfy the equation given below, as the number of customers at site k:

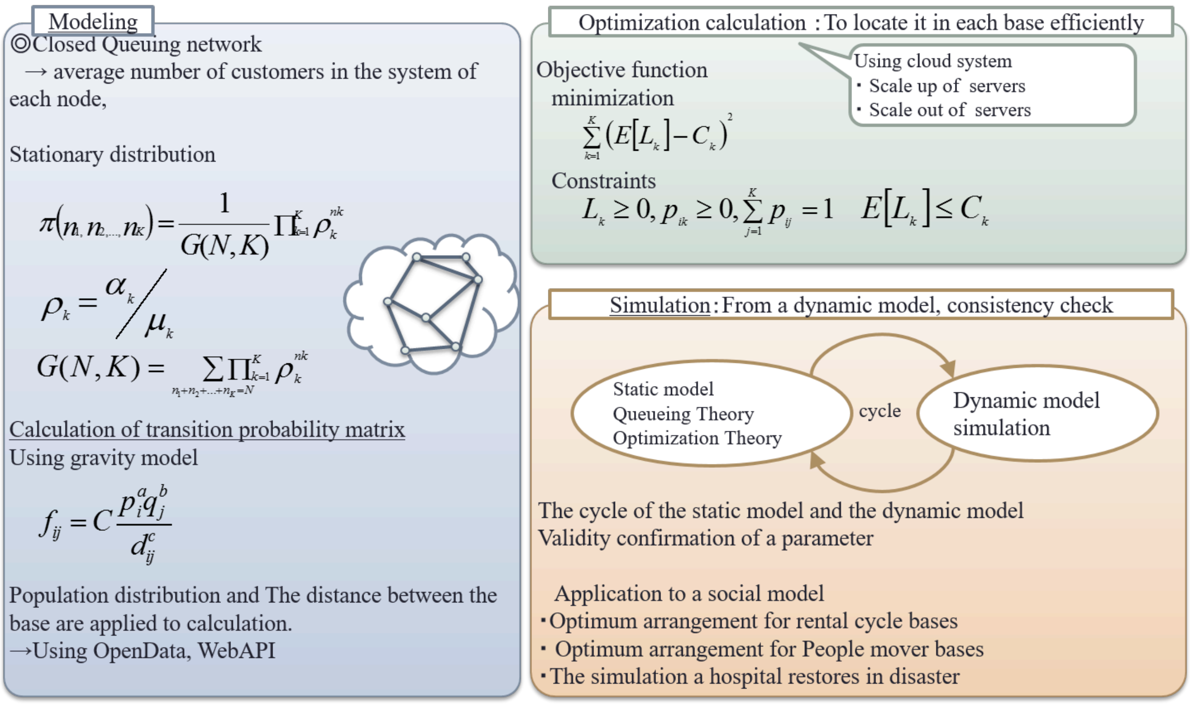

Figure 1 Outline for an analysis foundation for an optimal nodes placement

$$N = \sum_{k=1}^{K} n_k$$

Where n_k is the number of customers at site *k*.

iv. At site *k*, the service time followed an exponential distribution of service rate μ_k.

v. The rate of completed arrivals of customers from the inner network at site *k* is α_k.

vi. Customers who received service at site *i* move to site *j* with the probability as follows:

$$p_{ij} \qquad (1 \leq i, j \leq K, p_{ij} \geq 0, \textstyle\sum_{j=1}^{K} p_{ij} = 1)$$

We defined the service rate at each site as users' utilization frequency. In addition, α_k must satisfy the equation as follows:

$x_1 = 1, x_k = \sum_{j=1}^{k} x_j p_{jk}$, $(k=2,3,...,K)$ Moreover, $\rho_k = \alpha_k / \mu_k$, $(k=1,2,...,K)$

Therefore, the stationary distribution in which there are n_1 people in facility *1*,…, n_k people in facility *k* is as follows:

$$\pi(n_1, n_2, ..., n_k) = 1 / G(N,K) \prod_{k=1}^{K} \rho_k^{n_k}$$

Where $G(N,K) = \sum_{n_1+..n_k=N} \prod_{k=1}^{K} \rho_k^{n_k}$

We calculated transition probability p_{ij} according to the gravity model as follows:

f_{ij} : The amount of movement from region *i* to region *j*

p_i : The total amount of movement from region *i* as the departure place

q_j : The total amount of movement from region *j* as the arrival place

d_{ij} : The distance between regions *i* and *j*

C : The gravity model normalization constant: *0.145722117443322*

$$f_{ij} = C\frac{p_i^a q_j^b}{d_{ij}^c}, i \in K, j \in K$$

Here, *a* and *b* are the Population Parameters. *c* is the Distance Parameter. We compute the *a* power of p_i, the *b* power q_j and the *c* power of d_{ij} using these parameters. If we think d_{ij} is important, we enlarge the distance parameter of *c*. These parameters mean what we emphasize, distance or population, for transition probability in this model.
Normalizing f_{ij}, we get the transition probability p_{ij} . In this study, we performed calculations with *a* = *b* = *1* and *c* = *0.5*.

3. Configuration of the proposed system

In Figure. 2, we present the procedure used to compute the optimal placement of the nodes in our system. Here, region means the whole of the target area and area has the zip code, population. Get the transition probability from the gravity model, use the area as the minimum unit of gravity model.

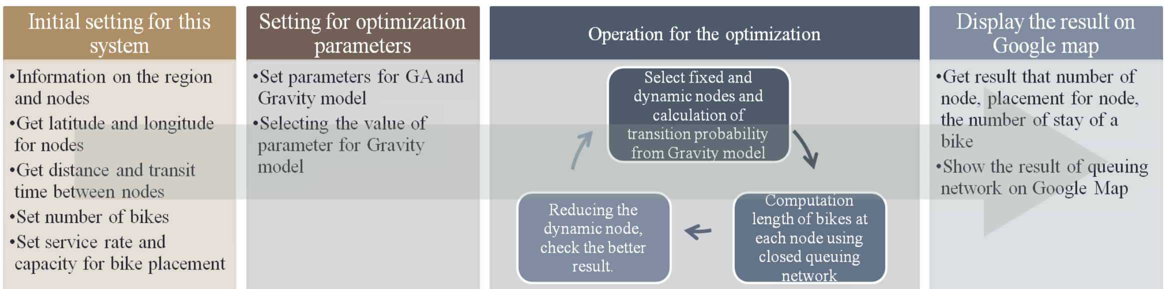

Figure 2 Procedure to compute the optimal placement of the nodes

3.1 Initial settings

Before the computations, we select the initial settings. The database of our system utilizes 2 tables for initial settings. In the first table, we enter the zip code data, consisting of zip code, state name, region name, city name, town name, and population. Next we input information data for the distribution nodes, consisting of node name, zip code, address, latitude, longitude, service rate, and capacity.

Provided the node information, we can compute the distance and duration between nodes *i* and *j*. In Fig. 3, we present the procedure to acquire information for all nodes. Commercially, we use Google Maps because we would like our system to be used in anywhere. By using Google Maps, we can effectively acquire the parameters used in our system and visualize locations. Moreover, we can minimize the setup time required to obtain the cost parameters, such as distance and transit time, between nodes. We specifically used GDirections of GoogleMapAPI Ver2 which it requires approximately 1 second to acquire the parameters for each combination of nodes. We use either the transit time or distance as the Distance parameter of the gravity model. Transit time and distance are used to confirm the tendency of direction for users in gravity model.

3.2 Optimization procedure

First, we select the number of nodes in the objects distribution system. There are two types of nodes, fixed and dynamic. We set *U* total number of nodes. If we select *m* fixed nodes, number of dynamic node is *U*–*m*. Then we create the gene that length is *U* and each element is node ID. And it consists of *m* fixed nodes and *U-m* dynamic node in Fig. 4. We may need to analyze for varying number of fixed nodes. After we select the fixed nodes, we select the best nodes from the dynamic nodes to compute the objective function using closed queueing network. So we get the average the queue length at each node. We should confirm the value of the objective function because we want to verify that the GA converges to plot change of value for the objective function. Next, we display the results on Google Maps.

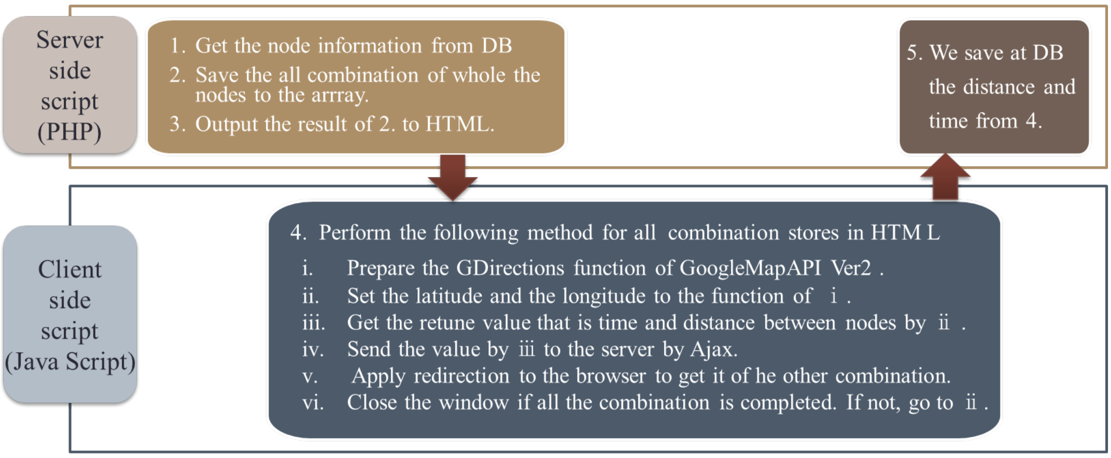

Figure 3 Parameter acquisition process for all nodes

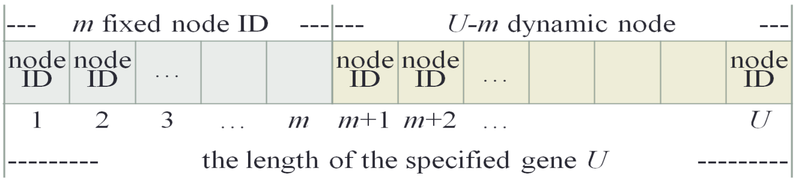

Figure 4 Composition of a gene

4. Conclusions

To increase the effectiveness of these objects distribution systems, it is important to carefully arrange the distribution nodes of the system. In this study, we optimize the arrangement of nodes in any region. If provided with regional information, such as zip code numbers, region names, node information, our approach can be applied to other locations. Moreover, using Google Maps we can compute the required parameters in a timely fashion. In order to solve this problem, we prepare the node candidate information exceeding *300* and *422* regional information.

Our proposed approach has several unique features. First, all parameter computations can be performed on the Cloud Computing using Google Maps. Next, using the gravity model, we can compute the transition probabilities through population and distance. It is important to decide transition probability of queueing network, so we decide it effectively to use the gravity model. Finally, we perform an effective analysis using a queuing network. On the basis of the results obtained, we are confident that our proposed approach can be used to generate effective arrangements of objects distribution nodes. This analysis foundation for an optimal nodes placement that we propose can apply it to many models and we can analyze such as node placement effectively by using this foundation.

References

Miyazawa, M.(1993), “Probability and Stochastic processes,” Kindai Kagaku-sha, Tokyo, Japan. (in Japanese).

Miyazawa, M.(2006) “Mathematical modeling for queues and its applications,” Makino-shoten, Tokyo, Japan., (in Japanese)

16:00 – 18:00	Session 5B (Floor 16)	Chair: Loo Hay Lee
	Theme: Ports (Intermodal terminal operations and intermodal transport planning)	

Scheduling and Routing of Trucks in Drayage Services with Foldable Containers
Ruiyou Zhang, Haishu Zhao and Shixin Liu

Operational Analysis Approach on Intermodal Terminal Considering Railway Traffic Linked with Container Terminal Based on Simulation
Chun Jin and Jingshu Wang

Integrated Yard Crane Deployment and Storage Allocation in a Transhipment Container Hub
Xinjia Jiang

Case Study of a Refrigerated Warehouse Design and Analysis using i-AOMA
Gyusung Cho and Kwangyeol Ryu

Scheduling and routing of trucks in drayage services with foldable containers

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(Extended abstract)

1. Introduction

Container drayage service is a key section in containerized logistics. Although the transportation distance in drayage is usually not long, its transportation cost per distance per container is usually very high (Cheung, Shi, Powell, & Simao, 2008). Furthermore, this section of transportation is the key source of shipment delays, road congestions, and carbon emissions.

Drayage of containers has attracted much academic attention in the last decade. See Steenken, Voß, & Stahlbock (2004) for a classification and literature review of the operations and container terminals and Stahlbock & Voss (2008) for a literature update. Also, see Goel & Gruhn (2008) for a description of a family of generalized vehicle routing problems.

The manufacturing technology of a type of foldable containers that could be folded and unfolded without additional equipments has become mature recently. A truck with a chassis for a forty feet container that is used most widely nowadays could carry up to four folded containers of this type. Moon, Do Ngoc, & Konings (2013) present the reposition of empty containers considering both standard and empty containers. However, the scenario that they study is the maritime transportation between terminals (ports). Similar research could also be found in Myung & Moon (2014) and Moon & Hong (2015).

This research presents the scheduling and routing of trucks in drayage of foldable containers. The definition of the problem with several basic assumptions is given in Section 2. Following that, the problem is formulated using an extended version of the DAOV (determined-activities-on-vertex) graph and mathematically formulated as a nonlinear programming model. Finally, the model is linearlized, solved using CPLEX, and validated.

2. Problem definition

A trucking company provides the drayage services in a local area using foldable containers. The company has a depot for parking trucks and stacking containers. A truck could carry a loaded container or up to four emptied and folded container. Drayage tasks could be divided into two types according to their directions: collection tasks and distribution tasks. In a collection task, a container of freight located at its shipper is to be packed using a container and delivered to the depot. On the contrast, in a distribution task, a loaded container located at the depot is to be delivered to its receiver and unpacked. Each shipper or receiver set a time window for the drayage operation. However, the depot could be visited at any time. The considering time horizon is usually one day. The optimizing criterion is the total operating time of all involved trucks.

Furthermore, the following basic assumptions are given:

- ✓ All information of the drayage service is given in advance and keeps unchanged in the time horizon.
- ✓ The trucks are initially located at the depot and should be returned to the depot finally.

- ✓ When a customer (shipper or receiver) packs or unpacks a container, the truck could leave the customer. A truck comes to pick up the packed / unpacked container when the operation is finished.

3. Problem formulation

Zhang, Yun, & Moon (2009) proposed a so-called DAOV graph to formulate a type of container drayage problem. In a DAOV graph, a series of continuous determined activities are defined as a vertex and the undetermined activities are formulated as arcs. We still use this idea to formulate the problem studied in this article. Differently to the graphs existing in literature (e.g., Zhang, Yun, & Moon (2009)), each drayage task in this problem is formulated as two vertexes. For any given task, the activities delivering the container to the corresponding customer are the first vertex and the activities picking up the container (and delivering it somewhere) are the second vertex.

Let $G = (V, A)$ be a DAOV graph formulating the problem. Here, V is the vertex set consisting of the virtual initial departure / final return vertex and the task vertexes. A is the arc set representing the transfer between vertexes.

For an easier presentation of the problem, the authors further assume that any truck either handles empty containers or handles loaded container in any time horizon. This assumption is somehow reasonable, at least to a certain degree, since the trucks are enough to handle the tasks in this problem.

So far, the problem could be formulated as the following two sub-problems. One sub-problem handles the transportation of loaded containers. One truck could carry only one loaded container. Therefore, this sub-problem is the multiple- travelling salesman problem with time windows (m-TSPTW). The second sub-problem handles the transportation of empty containers. Remember that a truck could carry up to four empty (folded) containers at a time. As a result, this sub-problem is similar to the multiple- vehicle routing problem with time windows (m-VRPTW) where the capacity of trucks is four. The co-relationship between them is the visiting time. Specifically, for any task, the container could be picked up only after the container is delivered to its customer and the packing/unpacking operation is finished. The objective function is the total travelling time of all involved trucks in the two sub-problems.

4. Solution method and results

The first sub-problem is an integer linear programming problem. However, the formulation of the second sub-problem is nonlinear. Remind that a truck could transport at most four folded containers at a time. Therefore, the transfer between tasks in this sub-problem depends on cases. For example, if a truck is carrying three empty containers, it could travel to a customer to pick a forth container without returning to the depot. However, if truck is carrying four containers, it must send the containers back to the depot before travelling a customer to pick up another container. Of course, if the next customer requires an empty container (collection task), the truck does not need to send the containers back to the depot even if it has already carried four empty containers.

We linearize the second sub-problem introducing additional binary variables. Thus, the whole problem is formulated as a mixed integer linear programming model. We generated a batch of instances of the drayage problem randomly to validate this method. The instances are solved using CPLEX optimizer embedded by Visual Studio C++. Preliminary results indicate that for small- and medium- sized instance, the solving time is acceptable. Compared to the problem using standard containers only, the introduction of foldable containers could save about one third of the total operating time. The further evaluation of this method including the solving of large-sized instances is ongoing.

References

Cheung, R. K., Shi, N., Powell, W. B., & Simao, H. P. (2008). An attribute-decision model for cross-border drayage problem. *Transportation Research Part E: Logistics and Transportation Review, 44*(2), 217-234.

Goel, A., & Gruhn, V. (2008). A general vehicle routing problem. *European Journal of Operational Research, 191*(3), 650-660.

Moon, I., Do Ngoc, A.-D., & Konings, R. (2013). Foldable and standard containers in empty container repositioning. *Transportation Research Part E: Logistics and Transportation Review, 49*(1), 107-124.

Moon, I., & Hong, H. (2015). Repositioning of empty containers using both standard and foldable containers. *Maritime Economics & Logistics, Accepted*.

Myung, Y.-S., & Moon, I. (2014). A network flow model for the optimal allocation of both foldable and standard containers. *Operations Research Letters, 42*(6), 484-488.

Stahlbock, R., & Voss, S. (2008). Operations research at container terminals: a literature update. *Or Spectrum, 30*(1), 1-52.

Steenken, D., Voß, S., & Stahlbock, R. (2004). Container terminal operation and operations research - a classification and literature review. *OR Spectrum, 26*(1), 3-49.

Zhang, R., Yun, W. Y., & Moon, I. (2009). A reactive tabu search algorithm for the multi-depot container truck transportation problem. *Transportation Research Part E: Logistics and Transportation Review, 45*(6), 904-914.

Operational analysis approach on intermodal terminal considering railway traffic linked with container terminal based on simulation

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1. Introduction

Maritime container terminals, as the logistics nodes and service centres, play an important role in international trade and regional economy development. However, the annual growth of port container throughput has caused serious problems on its surrounding areas, such as urban traffic congestion, noise, environmental pollution, and so on (Caris, Macharis & Janssens 2013; Seifi et al, 2014). Therefore, it becomes quite impressing to build a rail-road intermodal terminal to establish a low carbon transport system as well as improve the status of container transportation.

This paper focuses on the logistics operations assessment and operation coordination between a rail-road intermodal terminal and the maritime container port linking by a dedicated railway, and the aim is to accomplish the following aspects:

(1) Analyse the operational activities on a rail-road intermodal terminal, a container sea port, and a railway travel operations under a given operation resource configuration.
(2) Evaluate the degree of operational coordination among the three types of facilities.
(3) Propose the coordination plan by providing the optimal configuration plan for the three parts.

The contribution is to emphasize the operation coordination of the whole IMT and CT system, and to search a simulation-based approach to finding the optimal resource configuration and operation plan for the intermodal logistics facilities.

This paper proposes a discrete event simulation-based approach to analysing the logistics operations on the rail-road intermodal terminals with the characteristic of stochastic, dynamic activities. In this simulation model, the logistics operations system is modelled as a queuing network model, the operation performances include the operation efficiency, service quality, cycle time of service resource and carbon emission are traced by the simulation model. Finally, an actual case study is carried out to illustrate the effectiveness and validation of this simulation model.

2. System Description

For a freight transport network linking to a maritime container terminal, it is assumed that the surrounding freight road network of a metropolitan area is represented by a diagram N, which $N=(V, R, W)$, $V=\{v_1, \ldots v_i, \ldots, v_n\}$ is the set of the network nodes. It has a container terminal P , which $P \in V$. To ease future congestion of urban road freight, a dedicated rail-road container intermodal terminal is planned to build, whose location is M, $M \in V$. After M is completed, part of the containers between the P and M will pass through by rail transport. In this research, the operations in rail-rod intermodal terminal located at M, the maritime container terminal located at P, and the railway freight transport between M and P are considered. By analysing the activities of a certain system during observation time, it can explain how the intermodal terminal can improve the efficiency of logistics services, reduce carbon emissions. The architecture structure of this system with its surrounding transport network is shown as Figure 1.

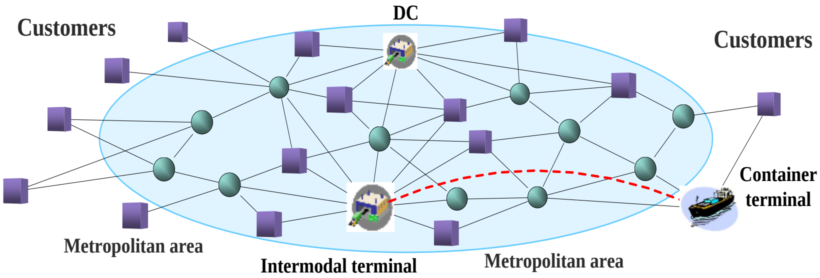

Figure 1: Architecture structure of the system with its surrounding transport network

The system includes two parts: the logistics infrastructure and the logistics activities (Hajipour et al, 2014). The infrastructure consists of the fixed elements as the service resource, including:

(1) Facility in Rail-road intermodal terminal: railway operation line, road operation line, container handling equipment, storage yard, yard operation equipment, and so on;

(2) Facility in container terminal: railway operation line, yards, gates and container handling equipment, and so on;

(3) Railway traffic system: railway line, railway container flat cars, operation line, and so on;

(4) Surrounding transport network: road network, rail network, distribution centres, and so on.

The function and structure of the whole system are shown in Fig.2.

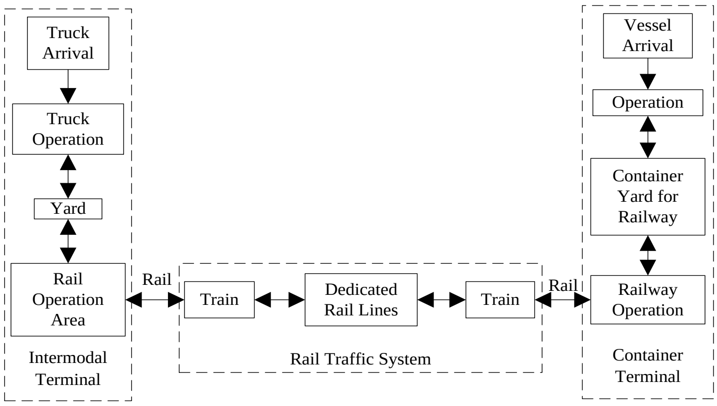

Figure2: The function and structure of the whole system

3. System Model

A discrete event simulation model is established to analyse this dynamic, stochastic operation system. In this simulation model, the logistics operations system was modelled as a queuing network model which has a limited capacity of more multi-server queuing model as shown in Fig.3. The main parameters are described below:

(1) The entity and service resources: model entities are container railway train and resources are the railway train in handling operations line, highway truck and container handling equipment.

(2) Arrival mode is from two directions; For railway, travel between the port and intermodal terminal as *nt* frequency and with a maximum of *Qt* TEU per trip per day; For container truck: Arrival *Qm* vehicles daily as Poisson distribution reach, including the picking import containers and sending export containers.

(3) The queuing process: queuing rule is first come, first served (FIFO).

(4) Service process: including process for railway and for container truck. The loading/unloading operation lines for the railway is *mr*, the capacity is *pr* TEU/min, the time for the operation process is *wr* min which is following the normal distribution.

(5) Assume the container storage capacity is sufficient in intermodal terminal.

In summary, the rail operations of this model can be seen as the D/G/ mr queuing model, road work can be viewed as the M/G/mt queuing model.

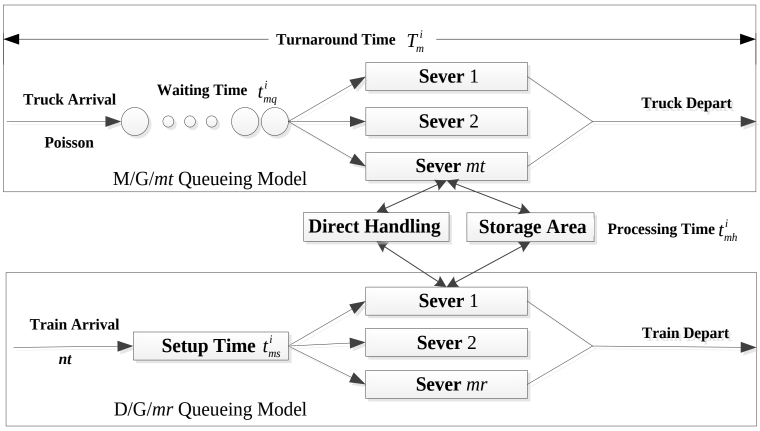

Figure 3: The queuing network model of the intermodal terminal

The simulation model is established with ARENA, as shown in Figure 4.

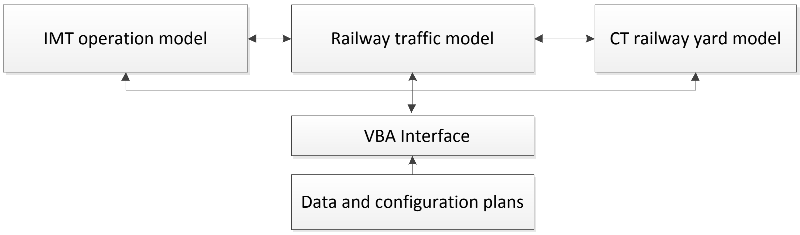

Figure 4: The structure of the simulation model

4. Results and conclusions

An actual case was simulated to verify the proposed model. The main simulation results are showed as below. The main information and data are obtained from the following website sources: The SAL report 'Metropolitan Intermodal Terminal Study 2011'(see http://shippingaustralia.com.au/publications/), The Bureau of Transport Statistics (BTS) (see http://www.bts.nsw.gov.au/Home/default.aspx), and the series of the project reports such as 'Major Project Assessment: Intermodal Logistics Centre, Enfield' (see NSW Department of Planning http://www.planning.nsw.gov.au), the website of Sydney Ports Corporation (see http://www.sydneyports.com.au/), and so on.

In this model, input parameters are divided into infrastructure data, operational data. The main input parameters are shown in Table 1.

Table 1: Main input parameters

Parameter	Value	Unit	Parameter	Value	Unit	Parameter	Value	Unit
Qs	*100000*	*TEU*	*my*	*4*	*number*	*nc*	*40*	*car*
Qt	*40*	*TEU*	*wr*	*2*	*min*	*Lr*	*18*	*km*
Arrivel	*M/G/mt*		*ns*	*4*	*trips*	*vr*	*54*	*km/h*
T	*168*	*hour*	*nt*	*1*	*number*	*hr*	*16*	*hour*
py	*0.5*	*TEU/min*	*dt*	*6*	*hour*	*ti*	*4*	*hour*

(1) Results from the operations on the current conditiion

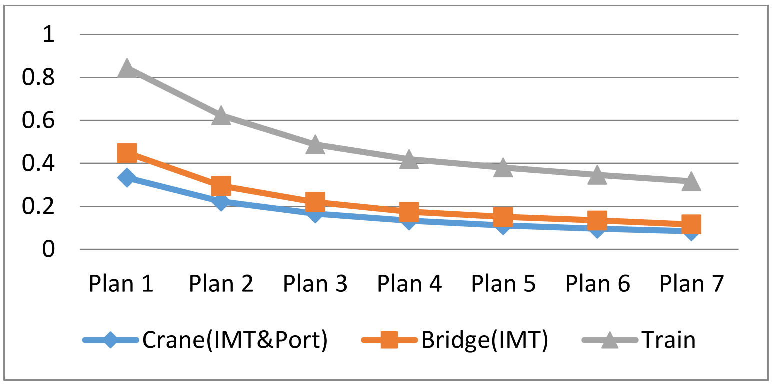

Figure 5: The performance of 7 configuration plans

(2) Results from changes in the business environment

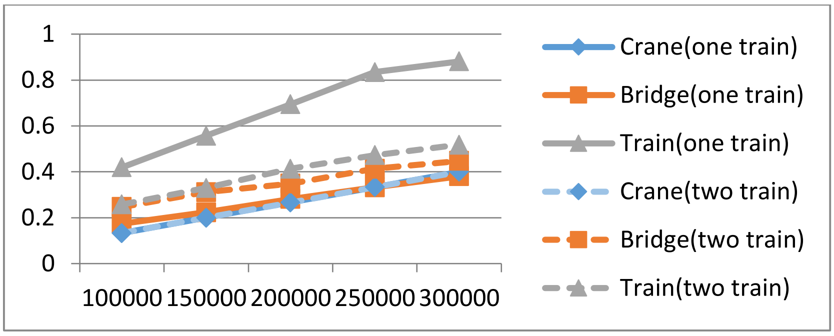

Figure 6: The percentage of performance indicators with the container volume changes

(3) Conclusions

First, this simulation model includes both the intermodal terminal and the railway traffic and the operations on the maritime container terminal, can analyse the detail operational activities under different configurations and find the bottleneck in this system.

Second, by this simulation model, the solution to operation coordination can be determined by finding the optimal resource configuration plan for the three subsystems.

Finally, an actual case study has been carried out and the effectiveness of the proposed model has been verified.

References

A Caris, C Macharis and G K Janssens (2013) Decision support in intermodal transport: A new research agenda. *Computers in Industry* , 64,105-112.

A Escudero, J S Mu ñUzuri, J Guadix (2013) Dynamic approach to solve the daily drayage problem with transit time uncertainty. *Computers in Industry*, 64(2),165-175.

V Hajipour, V Khodakarami, and M Tavana (2014) The Redundancy Queuing-Location-Allocation Problem: A Novel Approach, *IEEE TRANSACTIONS ON ENGINEERING MANAGEMENT*, 6(3),534-544.

R Ishfaq, C R Sox (2012) Design of intermodal logistics networks with hub delays, E*uropean Journal of Operational Research*, 220,629-641.

M S Seifi, N P Dellaert, W Nuijten, T Van Woensel and R Raoufi (2014) Multimodal freight transportation planning: A literature review. *European Journal of Operational Research*, 233,1-15.

M Zhang, B Wiegmans and L Tavasszy (2013) Optimization of multimodal networks including environmental costs: A model and findings for transport policy, *Computers in Industry*, 64,136-145.

Integrated Yard Crane Deployment and Storage Allocation in a Transhipment Container Hub

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Abstract:

This paper studies the integrated yard crane deployment and storage allocation in a busy transhipment hub, where a special "consignment strategy" is applied. Under this strategy, containers to the same destination vessel are usually stored together to facilitate the loading process and reduce the long distance travel of yard cranes. To manage the storage allocation process more efficiently, the port operator organizes the storage yard into several blocks, each containing 5 sub-blocks. The storage allocation is planned considering the practical requirements from traffic control, space capacity and yard crane workload, etc. Although the space allocation problem is rather complex in a transhipment hub, a few explorative studies succeeded to solve it under the consignment strategy. However, most of these studies assumed that yard cranes are always ready whenever needed, while the yard crane deployment problem was neglected. This may lead to not only unnecessary operational cost, but also the infeasibility of some storage allocation plan. In this work, the deployment of yard cranes is studied together with storage allocation to improve the situation.

Case Study of a Refrigerated Warehouse Design and Analysis using i-AOMA

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Abstract

The concept of integrated Aspect-Oriented Approach Modelling(i-AOMA) is based on the aspect-oriented programming that makes it possible to clearly express programs involving such aspect, including appropriate isolation, composition, and reuse of the aspect code. The i-AOAM should be built upon a conceptual framework and is to denote the space of modelling elements for specifying crosscutting concerns at a higher level of abstraction. In this paper, a methodology to design and analyse the logistics system using the i-AOMA is proposed. The new methodology applied at the case study of simulation model is based on a logistics system and it can be used for various simulation applications in developing reusable, extendible, and modifiable control software.

Keywords: Simulation, System Performance, Logistics System, integrated Aspect-Oriented Approach Modelling (i-AOMA).

1. Introduction

Traditional programming techniques help separating out the different concerns implemented in a software system, but there are some that cannot be clearly mapped to isolated units of implementation (Kim and Lee, 2009). The main idea of i-AOMA (integrated Aspect-Oriented Approach Modelling) is the modularization of these types of concerns. The purpose of this paper is to design a logistics system and analyse its performance. This paper also presents a real case study of the design and analysis of a refrigerated warehouse located at Busan, Korea based on the i-AOMA.

2. Concept of i-AOMA

The current simulation applied in the study use an object-oriented approach for analysis. While the object-oriented approach expresses an implementation of the system in vertical structure enabling an effective simulation of modelling and design, this approach only considers vertical or primary factors (Cui, Shi and Wang, 2015; Elia and Gnoni, 2015). Therefore, it is ineffective at accommodating the crossing concern of where numbers of modules can spread. Considering this disadvantage, an aspect-oriented approach has been utilized to present an alternative way to modularize the common area, eliminate repetition, as well as to change and reuse the model. As a result, it will improve the efficiency. The i-AOMA combines the OOM (Object Oriented Modelling) and the AOM (Aspect Oriented Modelling).The model can be depicted by an OOM-based simulation model, while an AOM-based simulation model can be used for implementing a model (Cho and Ryu, 2012). The object-oriented approach is used to develop physical control over the system, while managing the system is developed by the aspect-oriented approach. The advantage of i-AOMA is that it is able to support the construction of separate modules which is called as aspects that have the ability to cut across other modules defining behaviour that would otherwise be spread throughout other parts of the code, such as shown in Figure 1.

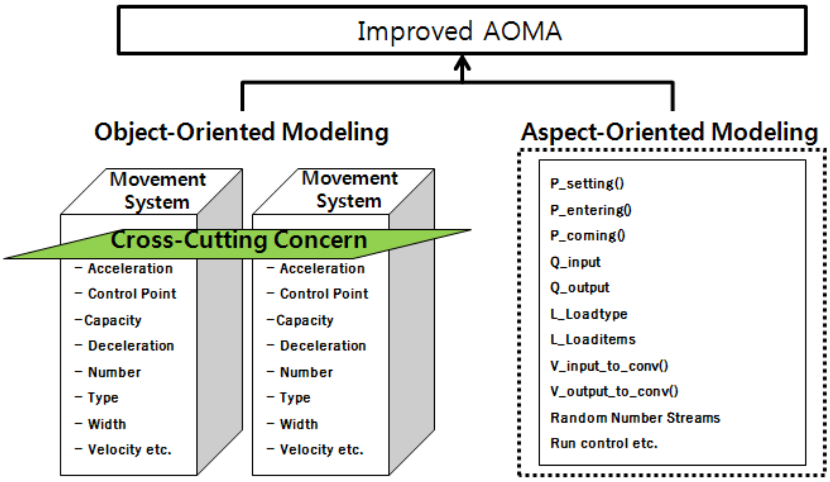

Figure 1: Concept of the i-AOMA

3. Design of Refrigerated Warehouses

A conventional forklift delivers the goods packed in pallets at the inbound yard. The racks include static racks, drive-through racks, and mobile racks. For automatic handling of palletized goods, modular packing and standardized pallets are desirable. In order to move pallets in and out, forklifts are used, together with automatic sliding doors. The forklifts remain permanently inside the cold storage chamber for order pickings. The same stored freight in each rack can be transported by a forklift to enhance the total stocks stored per rack and increase the cold storage in the racks. Generally, there are two main operations in refrigerated warehouses; the first operation is the storing process and the second operation is the releasing process following the orders of the freight owners.

The storing process into a refrigerated warehouse is described as follows.
1) Arriving of freight -> 2) Pulling the trucks -> 3) Loading the freights -> 4) Attaching the tags -> 5) Transferring using forklift trucks.
The releasing process from a refrigerated warehouse is described as follows.
1) Receiving requests -> 2) Searching for the freights -> 3) Looking for the pallets or unit loads -> 4) Transferring the requested pallets or unit loads into trucks.

In refrigerated warehouse, Very Narrow Aisle (VNA**)** forklift trucks used for handling unit loads in racked storage are categorized by the aisle widths they are designed to be operated in. Wide Aisle (WA) trucks are the standard Counter Balanced (CB) forklift trucks which are familiarly called as "CB forklift truck". Table 1 shows the comparisons of specifications between CB and VNA forklift truck.

Table 1: Comparison between CB forklift truck and VNA forklift truck

Index		CB forklift truck	VNA forklift truck
Weight (kg)		2000	2000
Minimum aisle width (m)		3.3 ~ 3.6	1.6~2.1
Horizontal speed (km/h)	Loaded	10.2	8.0
	Empty	10.4	8.5
Vertical speed (m/sec)	Loaded	0.26	0.35
	Empty	0.4	0.46
Highest reach (m)		7	10.2

Standardized VNA forklift truck consists of man-up order selectors used to manually handle less-than-pallet-load quantities and man-up turret trucks used to handle unit loads. In order to give some general comparisons, assuming a standard 101.6cm * 121.9cm load weighing approximately of 680kg and using wide aisles as the baseline, it is expected o be able to store 20%-25% more products by going to a narrow aisle system and 40%-50% more storage by going to a VNA system, such as shown in Table 2. A more complicated calculation is required when considering the option of going to narrow aisles and double-deep storage. When evaluating specific equipment and designing racking configurations, it is necessary to make decisions on the actual aisle width.

Table 2: Specifications of CB and VNA forklift truck

Division	CB forklift truck	VNA forklift truck
Aisle widths	3m	2m
Horizontal speed (loaded/empty)	10.2/10.4 (km/h)	8.0/8.5 (km/h)
Vertical speed (loaded/empty)	0.26/0.4 (m/sec)	0.35/0.46 (m/sec)
Capacity of one forklift	1 pallet	1 pallet
Loading & unloading time	40 sec	40 sec

First, we have analysed the logistics system with the operating data. Second, we have designed the system based on i-AOMA. Third, a simulation modelling is suggested by the logics considering the operating processes illustrated in Figure 2. Finally, we showed the results of simulation model and the best operating alternative, as shown in Figure 3.

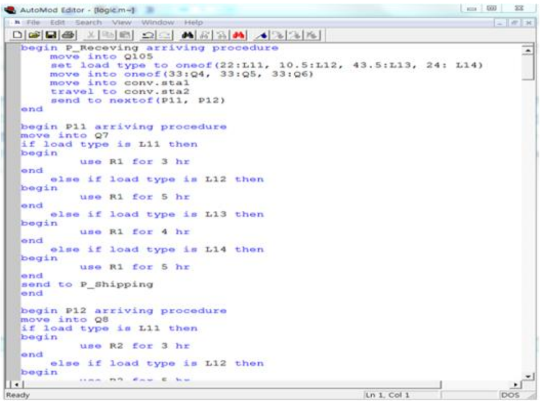

Figure 2: Logic of suggested Logistics System

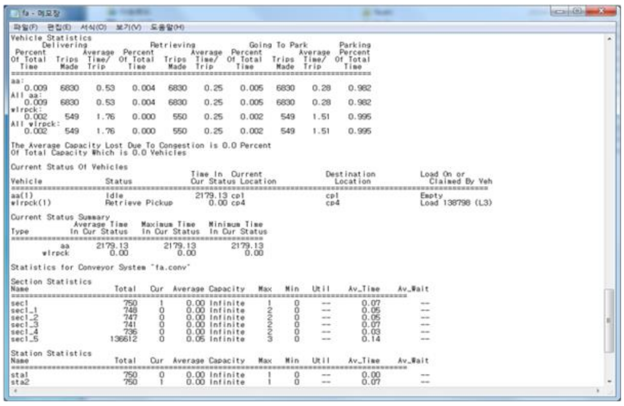

Figure 3: Results of the simulation Model

The average travelling rate by one CB forklift truck for delivering/retrieving the freight is about 93.8% and the parking rate is about 3.7%. The average travelling rate by two and three forklift trucks are 88.3% and 83.1%, respectively. The average travelling rate by one VNA forklift truck for delivering/retrieving the freight is about 96.9% and the parking rate is about 3.1%. The average travelling rate by one CB and that by one VNA forklift truck is same. It shows that substituting the VNA forklift trucks for CB forklift trucks is possible in this scenario in refrigerated warehouses and it can save the storage space, costs, etc. Generally the price of VNA forklift truck is cheaper than that of the CB forklift truck. The average travelling rate by two and three VNA forklift trucks are 91% and 82.2%, respectively. There are several differences in performance when more than two forklift trucks are used, as illustrated in Figure 4 and 5.

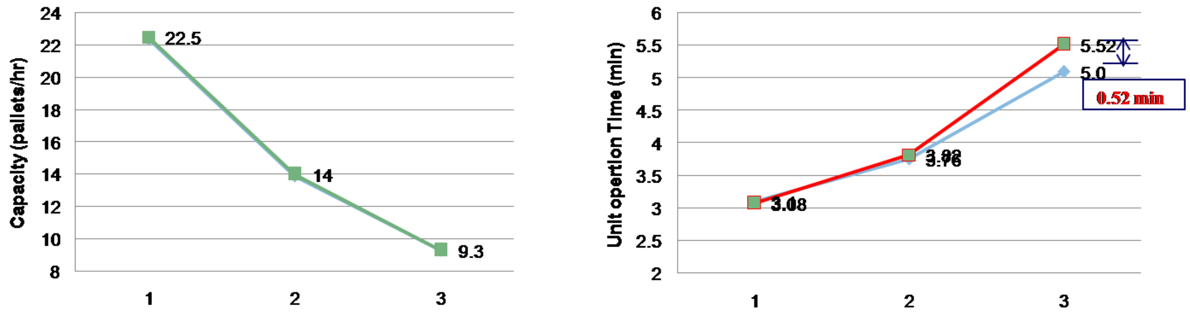

Figure 4:Performance of Equipments in Refrigerated Warehouse (1)

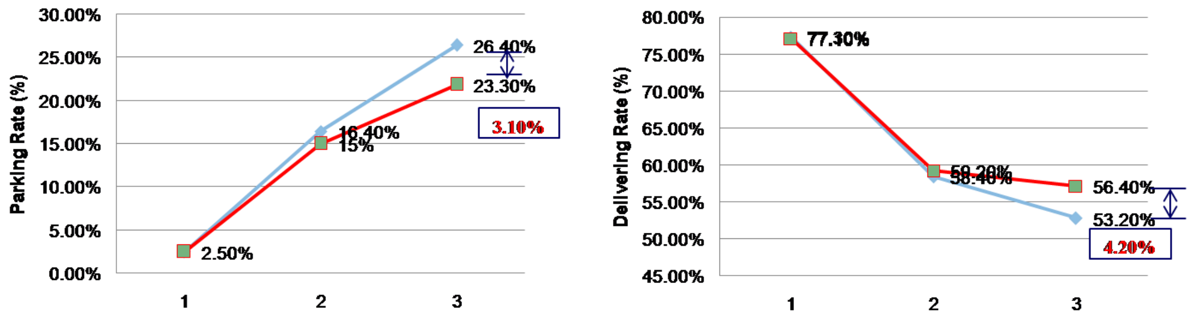

Figure 5:Performance of Equipments in Refrigerated Warehouse (2)

4. Conclusions

The i-AOMA proposed in this paper provides support for (1) describing crosscutting concern solutions as modelling views called aspects, (2) synthesizing an integrated model by composing aspect and primary model views, and (3) identifying and resolving conflicts and undesirable emergent properties that arise as a result of integrating aspect and primary models. This paper considers substituting VNA forklift trucks for CB forklift trucks in refrigerated warehouses and a supporting simulation model is developed by using the AutoMod simulator. Finally, this paper shows that the performance results of simulation models can be easily modified by changing the input factors on the OOM simulation model.

Acknowledgements

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References

Y Q Cui, J Y Shi and Z Wang (2015) Discrete Event Logistics Systems (DELS) simulation modeling incorporating two-step Remaining Useful Life (RUL), Computers in Industry, 72, 68-81.

V Elia and M G Gnoni (2015) Designing an effective closed loop system for pallet management, International Journal of Production Economics, 170, 730-740.

T G Kim and J J Lee (2009) Development of a graphical modeler for manipulating series data based on object-oriented technique, Journal of The Korean Society of Agricultural Engineers, 51(2), 43-49.

G S Cho and K Y Ryu (2011) Improved aspect-oriented modelling approach for business and manufacturing process simulation, ICIC Express Letters, 5(10), 3683-3688.

G S Cho and K Y Ryu (2012) A study on the business process management and modeling using i-AOMA, ICIC Express Letters, 6(3), 845-850.

09:00 – 10:30	Session 6A (Floor 17)	Chair: Kap Hwan Kim
	Theme: Industrial Session 1 (Logistics Technologies)	

A Study on Pick-Face Blocking Delay between two Pickers in a Wide-Aisle Circular Passage System
Boa nam, Jeonghwan Kim and Soondo Hong

How Much Energy Leaks Through a Loading Dock?
Yong-Joo Kim, Kyung-Ho Moon, Youn Keun Bhang and Jae Hyun Park

Impacts of Mega Vessel and Challenges to Ports
Hyongmo Jeon

A Study on an Order Batching Model Considering the Depot Selection
Jihyun Kim, Thuy Mo Nguyen and Soondo Hong

A study on pick-face blocking delay between two pickers in a wide-aisle circular passage system

Boa nam[1], *Jeonghwan Kim*[1], *Soondo Hong*[1*]

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Extended abstract submitted for presentation at the
6th International Conference on Logistics and Maritime Systems (Sydney, 21-23 June, 2016)

1. Introduction

This study addresses a pick-face blocking model and closed-form expression of two workers travelling with walk speed *m* (*m*=integer) in a wide-aisle circular-passage system of *n* stations and assuming *n*=*m*, 2*m*, ….. We develop a Discrete Time Markov Chain (DTMC) model to analyze the walks, picks, and blocked states of two workers, and derive a steady state probability the throughput loss in a closed-form expression. We validate the model with a simulation study to determine how the pass-allowance assumption can improve operational throughput compared to no-passing situations.

A one-way passage system can minimize the confusion of the workers in both directions in a wide aisle narrow aisle warehouse and simplify the transport protocol. The literature has studied the significance of blocking congestion in passage-aisle picking systems (Skufca 2005, Parikh and Meller 2010, Parikh and Meller 2009, Hong, et al. 2015, Hong, et al. 2013, Hong 2014, Gue, et al. 2006): the picker blocking delay in a narrow-aisle warehouse and the pick-face blocking delay in a wide-aisle warehouse. Picker blocking delay studies have relied on both analytical and simulation methods, whereas pick face blocking delay studies have relied on simulation and limited analytical models. The significance of congestion in wide-aisle warehouses is addressed by Parikh and Meller (2010) and Hong, Johnson and Peters (2013). They develop analytical throughput models of pick face blocking between two extreme walk speeds. This paper develops a DTMC model when two workers travel a circular passage system with stochastic service time and walk speed *m*, which is a practical walk speed case. This paper derives a closed-form expression of the throughput model considering blocking delay.

2. Problem definition

A system is a circular-aisle warehouse, a service station is a pick face, a service is a pick, and workers provide a picking service. Figure1 shows a circular-aisle warehouse with linked *n* pick faces ($n>m$) and workers circulating in a clockwise direction. A stochastic model determines the number of picks at a pick face. Workers pick an item with probability *p*. They spend unit time to conduct one pick. When no pick is chosen (1-*p*), they move to the next service station with speed *m*, i.e., the walk time between two pick faces is 1/*m*. After a pick, each worker repeats the same choice independently of the previous action. Workers retrieve items from both sides of a pick face. The number of picks at a pick face is determined by a series of successes. The retrieval time is one unit time regardless of the sides and shelving height. Blocking occurs under a passing allowance, e.g., when two workers are in neighboring pick faces, if the downstream worker is picking, the upstream worker enters the next pick face but only remains idle when the downstream worker needs a pick at the same pick face. When the blocking worker completes pick(s) and a blocking situation is released as the blocking worker moves to the next pick face, the upstream worker starts a pick simultaneously.

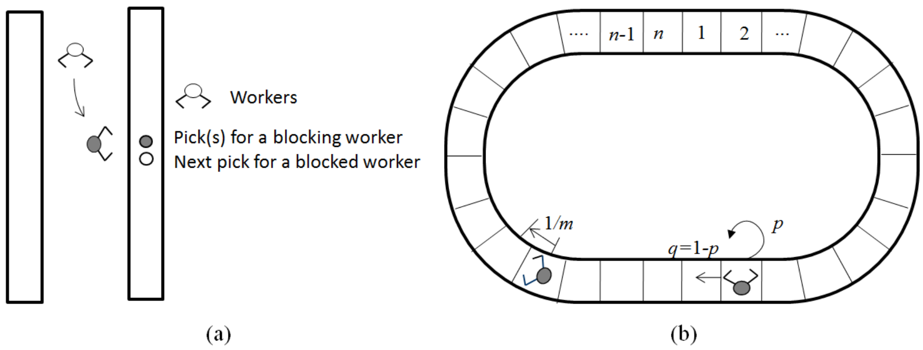

Figure 1: A typical example of (a) pick-face blocking and (b) Wide-aisle circular passage system.

The ratio of the number of pick faces *n* to the walk speed *m* influences the modeling step. Our model assumes that *n* % *m* = 0, where % is the notation for the modulation operator and *n* > *m*. As a performance measure, we obtain the percentage of time blocked (= the time blocked of a worker/the worker's total time in the system), and denote it as *b*(*p*, *m*, *n*).

3. Analytical model

Assume that *m* is integer and *n % m*=0. Let D_t denote the distance between worker 1 and worker 2 at time *t*. Express the distance as (*n* + (worker 1 position)−(worker 2 position)) % *n* ranging from 0 to *n*-1. Define state $S_t = b$ (*block*) representing worker 1 blocking worker 2 or worker 2 blocking worker 1, and the states [0, 1, 2, … , *n*-1] given by $S_t = D_t$. Summarize all states by the sequence [*b*, 0, 1, 2, … , *n*-1]. Note that sequence [*b*, 0, 1, 2, … , *n*-1] is not a Markov chain, i.e.,, if a worker picked during the last epoch, the worker must keep picking during this epoch, since the pick time requires two epochs. Therefore, D_{t+1} depends on D_t and on the action of the workers in the previous step. Next, establish the Markov property by including the history of the previous step in the state. Divide a pick time into *m* sub-states (i.e., epochs). Label the sub-states as d_{xy}, where *x* and *y* represent the number of epochs remaining until the next decision of workers 1 and 2 is available.

The blocking probability of worker 1 is

$$b(p,m,n) = \frac{mp^2}{2mp^2 + 2(1-p) + (m-1)[2p(2-p) + (m-2)p^2(2-p)] + \frac{(n-m)}{m}\begin{bmatrix}(2-p)\\ +(m-1)2p(2-p) + (m-1)^2p^2(2-p)\end{bmatrix}} \quad (1)$$

4. Simulation validation

We conduct a comparison of Equation (1) on a simulation result to obtain the gap between the performances of the simulation model and the analytical model in terms of the difference of time blocked (Diff % = |the percentage of time blocked by the analytical model – the percentage of time blocked by the simulation model|/(the percentage of the time blocked by the analytical model) * 100). When *m* of a 20 pick face circular-aisle system = 10, 5, and 2, the error gaps on average are 0.09, 0.09, and 0.21%. These results show that the analytical model accurately approximates blocking in a circular-aisle system.

Acknowledgements

This research was supported by Basic Science Research Program through the National Research

Foundation of Korea (NRF) funded by the Ministry of Education (2014R1A1A2053550) and supported by the Ministry of Trade, Industry and Energy (MOTIE) and Korea Institute for Advancement of Technology (KIAT) through the International Cooperative R&D program.

References

Skufca, J.D. (2005) k Workers in a circular warehouse: a random walk on a circle, without passing. SIAM Review,47, 301-314.

Parikh, P.J. and Meller, R.D. (2010) A note on worker blocking in narrow-aisle order picking systems when pick time is non-deterministic. IIE Transactions,42, 392-404.

Parikh, P.J. and Meller, R.D. (2009) Estimating picker blocking in wide-aisle order picking systems. IIE Transactions,41, 232-246.

Hong, S., Johnson, A.L. and Peters, B.A. (2015) Quantifying picker blocking in a bucket brigade order picking system. International Journal of Production Economics,170, 862-873.

Hong, S., Johnson, A.L. and Peters, B.A. (2013) A note on picker blocking models in a parallel-aisle order picking system. IIE Transactions,45, 1345-1355.

Hong, S. (2014) Two-worker blocking congestion model with walk speed m in a no-passing circular passage system. European Journal of Operational Research,235, 687-696.

Gue, K.R., Meller, R.D. and Skufca, J.D. (2006) The effects of pick density on order picking areas with narrow aisles. IIE Transactions,38, 859-868.

How much energy leaks through a loading dock?

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Extended abstract submitted for presentation at the
6th International Conference on Logistics and Maritime Systems (Sydney, 21-23 June, 2016)

1. Introduction

Cold storage warehouses use most of electric energy in running refrigeration machine. Electricity consumed in a warehouse to run refrigeration machine consists of heat through the wall, heat from the goods, heat from the workers, heat from the machines such as forklifts, heat from the lights and heat convected through the dock where trucks are loaded and unloaded.

To prevent the air leakage through loading dock, various systems such as dock shelter and air shelter have been used. In Korea, dock seal is popularly used rather than the above systems due to lower price and high space efficiency. However the dock seal system has a weakness that it is hard to seal the gap between a truck and a loading dock since dimensions of trucks are different.

Figure 1: Air shelter (Kelly), Dock Shelter (ASSA ABLOY Entrance system), Dock Seal

Figure 2: Gap between the cargo box and loading dock

This study aims to analyse how much energy leaks through the loading dock.

2. Research process (Times New Roman Bold 11pt)

We first measure air velocity through the dock and temperatures at various locations. Temperature inside the warehouse is maintained at about 7℃.

Figure 2: Measurement position

CFD (Computational Fluid Dynamics) is used considering heat transfer by conduction and convection to estimate energy loss. For CFD we generate 3D model of the space including the loading dock, truck and inside of the warehouse.

3. Results and conclusions

Calculation results shows that the energy loss through the dock is much larger than the heat transfer through the wall by conduction during loading/unloading time.

Keywords: Cold storage warehouse, CFD, Refrigeration machine, Loading dock

Impacts of Mega Vessel and Challenges to Ports

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Extended abstract submitted for presentation at the
6th International Conference on Logistics and Maritime Systems (Sydney, 21-23 June, 2016)

1. Introduction

Before 2020, it is expected that over 24,000 TEU size vessels will sail on the major trade route between North-east Asia and Europe. Due to cascading effect, the size of major vessels in Pacific route between Asia and America are also increasing rapidly.

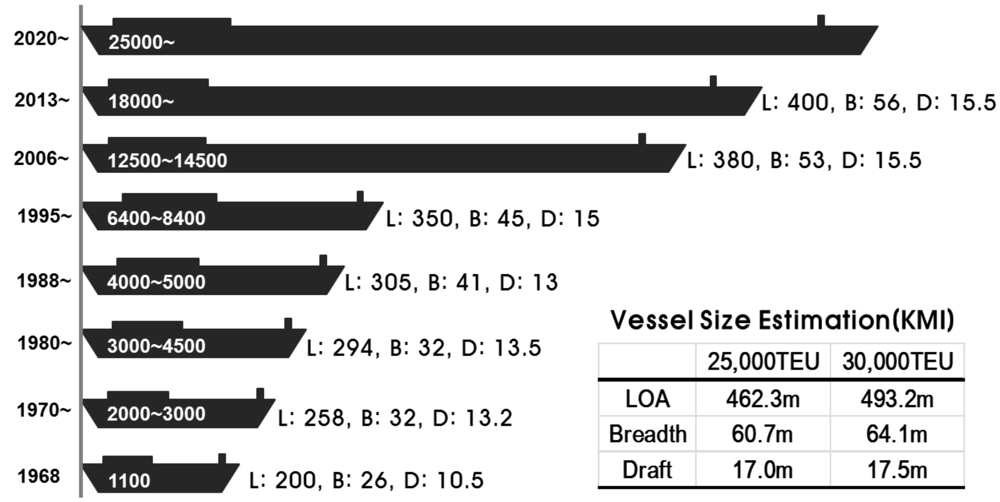

Figure 1: Container Vessels Size Changes

Due to economy of vessel size, major container liners will keep ordering larger vessels, but it becomes kinds of tough challenges to container terminals.

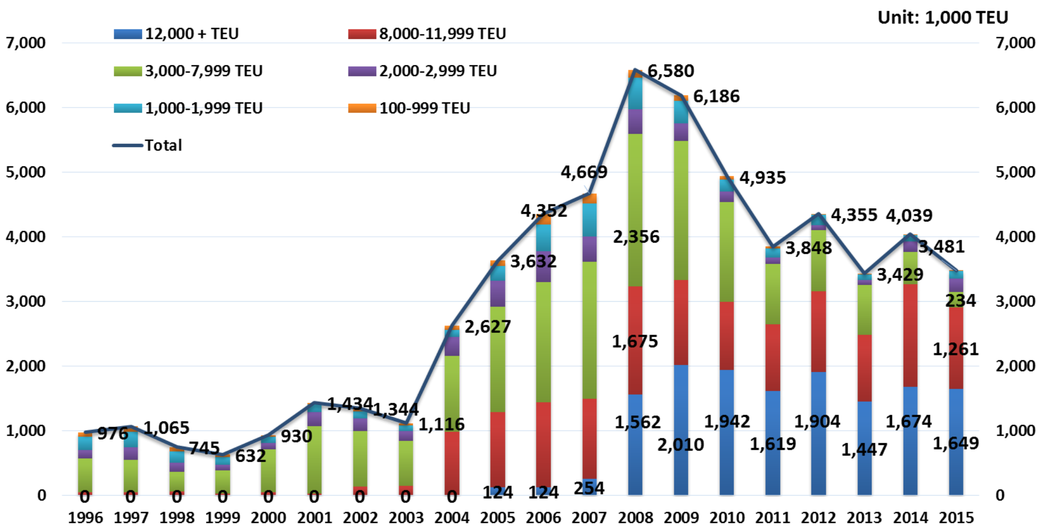

Figure 2: Mega Vessel

2. Challenges

The major container terminals are already have problems in handling over 18,000teu vessels due to their limited crane productivity and quay capacity. Also, because of traffic concentration due to mega vessels, higher yard occupation rates are also major challenges to ports.

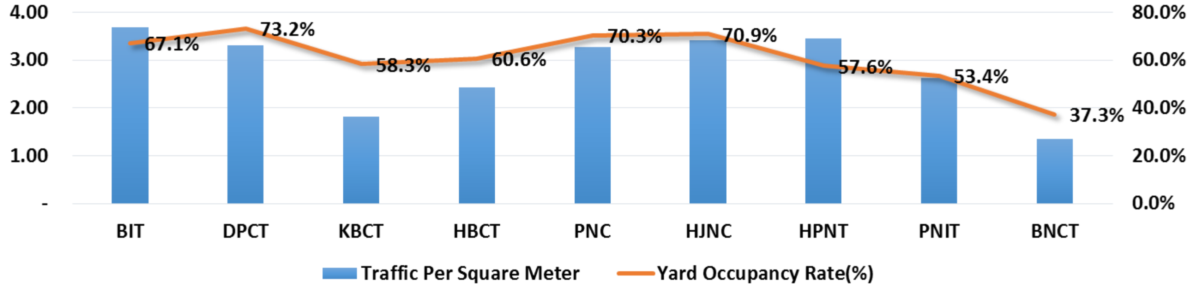

Figure 3: Busan Port Yard Occupancy Rate

3. Port Strategic Recommendations for the Challenges

Port resource sharing, information consolidation, yard space expanding by physically or virtually, new equipment technologies, automation, and whole new concept of container terminal can be considered as solutions for the mega container vessel issues.

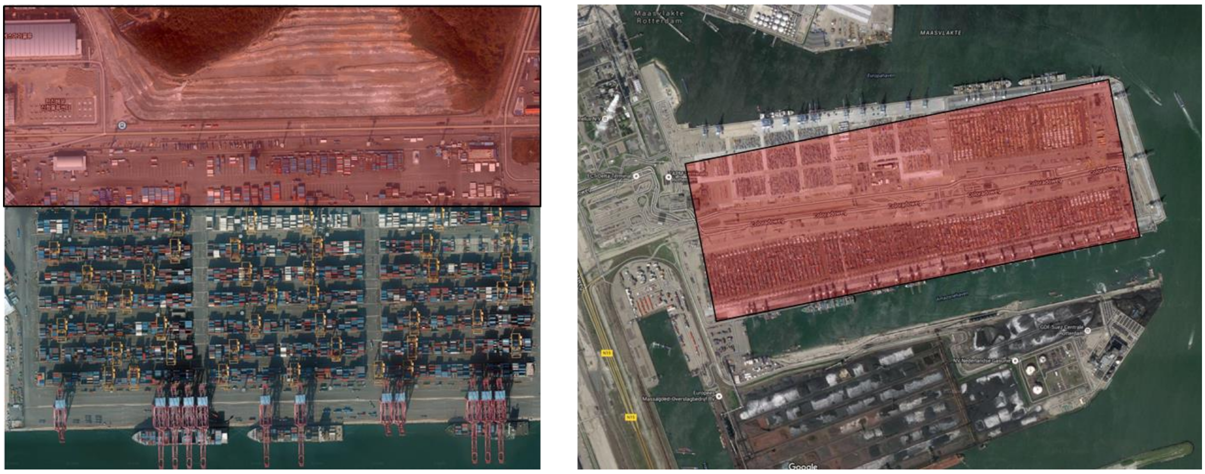

Figure 4: Yard Space Expansion

References

Andrew Penfold, CARRIER STRATEGIES, COST vs VALUE & THE SUPPLY CHAIN IMPACT, Ocean Shipping Consultations, TOC Europe 2015

Clarkson Order Book 2015.12.18.

A study on an order batching model considering the depot selection

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1. Introduction

We are interested in order picking situations where the order batching operation accompanies additional decision to optimize the operation by considering tactical strategy such as depot selection, which is presented by Hong, et al. (2014). Usually, batch picking optimizes an operational situation for pickers to start from a single depot with an identical cart in a fixed operational zone. However, in reality, operational environments are more complex. When we visit a traditional warehouse, pickers probably alternates cart depots, manage different sizes of picking vehicles, and retrieve items over their operational zones. This study defines this situation of the joint order batching and depot selecting problem (JOBDS) because multiple depots require a separate process: determine the depot while determining batches and their routes.

This study presents a new model which groups orders to batches to minimize the total travel distance of pickers constrained by vehicle capacity, determines a flexible operational policy for depots, and optimizes the batch combinations.

2. Problem definition

An order picking system similar to those described in Hong, Johnson and Peters (2014) is considered in this article. Figure 1 shows a model with eight one-way parallel-aisle and two cross-aisles located in the front and back of the layout connecting the parallel aisles. We have two depots station are located in front of the left-most and between aisles and one picker at the depot. A picker starts from his depot and through all necessary aisles to collect a batch and then returns to the starting depot. Pickers need not traverse every aisle but if they enter an aisle they have to pass through an aisle. If a picker has free time, he can move to another depot, and we assume that this moving time is a small number and does not impact the travel length. Order pickers can retrieve items at 20 storage locations per aisle. The travel length isn't impact the height of the shelves and the pick time.

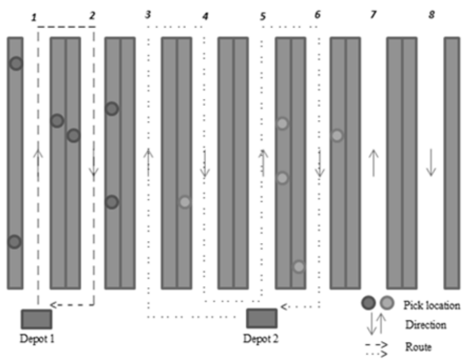

Figure 1: An eight-aisle joint order batching and depot selecting system.

An order picker transports ten bins on a cart to pick ten different items and has a distance-dependent travel time but a constant walking speed and pick time per item. In determining batches, we assume no blocking delays and minimize total retrieval distance. Furthermore, each aisle should use one-way traversal routing. We have the same routes for per picker starts from their depot, but the travel length per route is different.

3. Formulation

We consider both sort-while- pick and pick-then-sort order picking strategies. CAPA is the capacity of the cart. Q_o becomes the number of line items in order o. In the case of pick-then-sort picking strategy, CAPA is measured in units of items and Q_o is the number of items in order Q. For the case of the sort-while-pick order picking strategy, CAPA is measured in units of orders and Q_o has a value of one. The detail formula is as follows:

Indices and sets:

D is the set of depots and its index d $\in$ O.

O is the set of orders and its index o $\in$ O.

B is the set for batches and its index b $\in$ B.

A is the set of aisles and its index $a \in A$.

R_d is the set of routes and its index $r_d \in R_d$.

Parameters:

CAPA is the capacity of a cart.

LT_{r_d} is the length of route r_d.

Q_o is the number of line items in order o.

$$OA_{oa} = \begin{cases} 1 & \text{if order } o \text{ passes through aisle } a \text{(order } o \text{ has at least one pick in aisle } a\text{)}, \\ 0 & \text{otherwise.} \end{cases}$$

$$RA_{r_d a} = \begin{cases} 1 & \text{if route } r \text{ passes through aisle } a, \\ 0 & \text{otherwise.} \end{cases}$$

Decision variables:

$$X_{ob} = \begin{cases} 1 & \text{if order } o \text{ is assgines to batch } b, \\ 0 & \text{otherwise.} \end{cases}$$

$$Y_{br_d} = \begin{cases} 1 & \text{if batch } b \text{ takes route } r_d, \\ 0 & \text{otherwise.} \end{cases}$$

Formulation:

$$\text{(JOBDS) min} \quad \sum_{b\in B}\sum_{r_d\in R_d} LT_{r_d} Y_{br_d} \qquad (1)$$

Subject to

$$\sum_{b\in B} X_{ob} = 1, \qquad \forall o \in O, \qquad (2)$$

$$\sum_{o\in O} Q_o \times X_{ob} \le CAPA, \qquad \forall b \in B, \qquad (3)$$

$$X_{ob} \times OA_{oa} \le \sum_{d\in D}\sum_{r_d\in R_d} RA_{r_d a} Y_{br_d}, \qquad \forall a \in A, \forall o \in O, \forall r_d \in R_d, \qquad (4)$$

$$X_{ob} = \{0,1\} \qquad \forall o \in O, \forall b \in B, \qquad (5)$$

$$Y_{br_d} = \{0,1\} \qquad \forall b \in B, \forall r_d \in R_d, \qquad (6)$$

The objective function (1) minimizes the total travel distance. Constraint (2) denotes that all orders should be assigned to batches and an order cannot be separated into multiple batches. In constraint (3), a batch should not exceed the capacity constraint of cart. Constraint (4) ensures that the aisle incidence vector of route *r* to which batch b is assigned should contain the aisle incidence vector of orders in batch b. constraints (5) and (6) define the variable domains.

4. Experimental results

We evaluate the quality of the objective value and computing time of JOBDS problem and the traditional single depot order batching (SOB) and implement the formulations using IBM ILOG CPLEX 12.6. The executable files run on Windows 7 (Intel Xeon 2.80 Ghz CPU, 68 GB memory). We apply order batching situations for the size of problem 50 orders and 100 orders over 20 instances with the order size = 2. We observe that the JOBDS reduces the objective value from 2.13% to 7.14% for pick-then-sort and strategy from 1.33% to 8.99% for sort-while-pick strategy in a 50 order size. With the size of problem 100 orders, the objective value is more improved (3.57~9.09% with pick-then-sort and strategy and 6.04~10.3% with sort-while-pick strategy).

Acknowledgments

This work was supported by the BK21 plus program through the National Research Foundation (NRF) funded by the Ministry of Education of Korea and supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (2014R1A1A2053550).

References

Hong, S., Johnson, A.L. and Peters, B.A. (2014) Order batching with time constraints in a parallel-aisle warehouse: A multiple-policy approach, in Progress in Material Handling Research: Proceedings of 2014 International Material Handling Research Colloquium (IMHRC), The Material Handling Institue, Charlotte, NC, USA.

09:00 – 10:30 **Session 6B (Floor 16)** **Chair: Collins Teye**

Theme: Ports (Straddle Carrier Automation and Routing of AGVs in container terminals)

Straddle Carrier Automation - An Example of Research to Commercialisation
Anil Agrawal and Haye Lau

A Two-Stage Approach for Large Scale AGV Routing in the Automated Container Terminal
Zhipeng Qiu, Ek Peng Chew and Loo Hay Lee

Real-time Deadlock-free Routing for AGV System in Container Terminal
Qitong Zhao, Ek Peng Chew and Loo Hay Lee

Straddle Carrier Automation – An example of research to commercialisation

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Extended abstract submitted for presentation at the
6th International Conference on Logistics and Maritime Systems (Sydney, 21-23 June, 2016)

1. Summary

The Straddle Carrier Automation research project at the University of Sydney was approved in 1996, with commercialisation completed in 2005, when 14 automated straddle carriers operated at Patrick's Fisherman Island container terminal in Brisbane, Australia. It took ten years for the second container terminal at Port Botany, Sydney to adapt the same technology.

This presentation provides background on the Australian-developed AutoStrad technology from a commercial perspective, and highlights the opportunities and challenges ahead.

Figure 1: AutoStrads in Port Botany, Sydney (Peter Rae, Sydney Morning Herald)

2. Note to organisers

Please excuse the brevity of the abstract. It is intended to summarise the content of this proposed talk (to be presented by Anil Agrawal, Product Manager of Horizontal Transport at Kalmar) about the AutoStrad project deployments from a broader commercial perspective, which from prior correspondence we understand may be of interest, particularly due to the location of this conference and the topical nature of the recent Patrick Port Botany automation rollout.

References

Rae, P, 'Sydney's Patrick terminal goes automated, with fewer staff but dancing robots', Sydney Morning Herald, June 17, 2015

A Two-Stage Approach for Large Scale AGV Routing in the Automated Container Terminal

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Extended abstract submitted for presentation at the
6th International Conference on Logistics and Maritime Systems (Sydney, 21-23 June, 2016)

1. Introduction

AGVs as the automated transportation equipment are widely used in the automated container terminal (ACT) to carry the containers from the quayside to the yard storage area or vice versa. These AGVs are free ranging with their routes programmed in the software in advance and therefore the routes can be adjusted relatively easily. This characteristic of free-ranging provides the flexibility for route selection, but also brings the challenge for AGV control. As the free ranging AGVs with a tremendous number are moving in a complicated path network (see Fig.1) with parallel lanes and intersections, the scale of AGV operations in the mega container terminal becomes very large and a lot of potential conflicts among AGVs can be caused which results in system inefficiency and greatly reduces the operation performance.

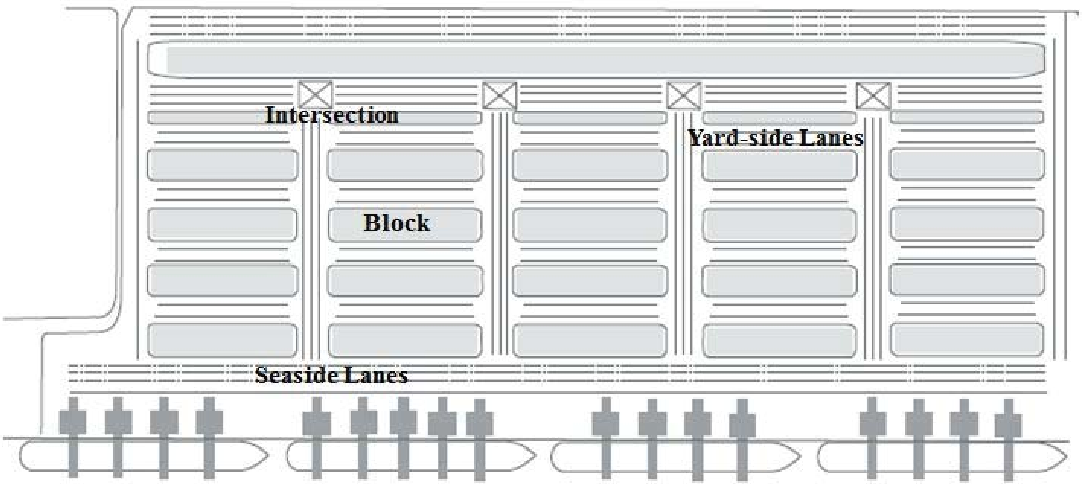

Figure 1: Layout of the automated container terminal

The large-scale AGV routing in an ACT is recognized to be extremely difficult not only because of its combinatorial nature of integer optimization but also its problem size. A large number of operating AGVs, multiple routes for each execution and enormous conflict-free constraints together explain the complexity of the problem. Additionally, the real-time control is required from a practical perspective. Therefore, the proposed algorithm has to be developed so that the high quality solution can be efficiently provided within the reasonable computational time.

However, most of current studies focus on the AGVs routing or scheduling with a very limited number of AGVs. Corréa et al. 2007 can only allow its hybrid method to solve instances with up to six AGVs while Desaulniers et al. 2003 are four and Langevin et al.1996 are two. Moreover, the real-time of AGV routing or scheduling and an effective control mechanism for AGVs under a large scale problem are absent in these studies (Gawrilow et al. 2008, Qiu and Hsu 2000, Zeng and Hsu. 2008). This study attempts to fill this gap, by considering free-ranging AGV routing and scheduling simultaneously in a large scale. Meanwhile, the corresponding algorithms are proposed to efficiently obtain the solution and the AGV control mechanism is also provided to achieve the system conflict-free and effectively control of AGVs.

The rest of the sections will be organized as follows. Section 2 briefly discusses a two-stage iterative algorithm and an improved rule-based algorithm. Section 3 is devoted to some preliminary results. The last section 4 shares roadmap for the future works.

2. Methodology

An overview of the two-stage approach used in this study is shown in Figure 2.

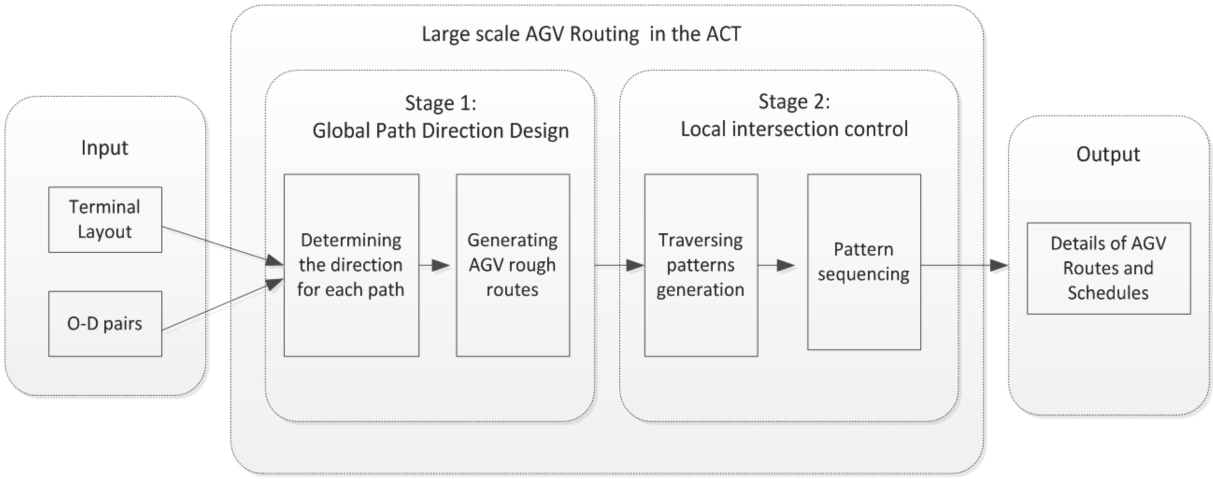

Figure 2: An overview of the two-stage approach

2.1. Mathematic Model and Two-stage Decomposed Approach

To describe and highlight the complexity of the original problem which integrates two well-know and hard combinatorial problems, namely routing and scheduling, a mixed integer formulation is first presented. In this MIP model, the routes and exact schedules for AGVs are regarded as decision variables to be determined based on zone concept. The overall objective is to find the routes and schedules for all the AGVs in the system to minimize the makespan and avoid the conflicts.

Just like the job-shop scheduling problem which is proved to be a NP-hard problem (Bagchi 2001, Nagar et al. 1995), it will have a high computational cost to find a good feasible solution if the model is directly solved with commercial software such as CPLEX in a large scale size. Therefore, one possible way to deal with such a complex problem is to decompose it into smaller problems for which the optimal or near-optimal solution can be determined. The key idea of the approach proposed in this study is to properly decompose the original problem into two major sub-problems (see Fig 2), namely, the route selection based on global path direction design and the AGVs scheduling under the local intersection control, which can be solved efficiently, even real time.

Different from the conventional vehicle routing problem which usually concerns whether there exists an optimal routes leading to a given destination, the AGV routing problem in ACT is a more time-critical one in which when and how an AGV gets to its destination should be emphasized (Qiu and Hsu 2000). Especially, when the problem comes to such a large size terminal and totally free-ranging AGVs, the path layout and system control mechanism should not be ignored if a good plan of routing and scheduling want to be reached. Therefore, a mathematical model is provided to optimize the path layout in stage 1 and then stage 2 shows a decentralized control mechanism to lead the AGVs to efficiently traverse one specific intersection.

2.2. Stage 1: Global Path Direction Design

AGVs used in the terminal are free-ranging which brings them a great flexibility to travel on a bidirectional path. It indicates the number of alternative routes for each AGV is huge. When it extends to a multitude of AGVs which are operating in a mega terminal at the same time, the number of the possible routes will become tremendous. Moreover, the potential conflicts or congestions in the intersections may be frequently caused because of the completely free traveling of AGVs.

Learning from the traffic engineering, the regulation of only allowing one direction for vehicles is adopted when the traffic is heavy. Motivated by this, a novel idea for this AGV routing in mega terminal is to attempt to reduce the conflicts or congestions in the intersections by regulating the path to be unidirectional. The benefits brought by this idea not only exist in reducing the interactions among the AGVs but also exist in reducing possible movements in the intersections which may allow the efficiency of scheduling in the local control.

In this stage, an integer programming model is presented to determine the path direction for the whole mega terminal using the given input of O-D pairs and terminal layout. The rough route (referring to traveling path with the absent of exact traveling lane and schedule) for each O-D is also generated in the model. The objective is to minimize the makespan. Two binary decision variables are introduced, one used to control the path direction and the other to decide the route. A set of constraints is introduced to establish the connection between the path direction and selected route and also enforce a traffic flow limit on the relevant paths.

2.3. Stage 2: Local Intersection Control

As stated, the main issues in this large size problem are to reduce traffic congestion and to alleviate the potential interactions among the AGVs. To well address the above issues, traffic control is regarded as one of the most efficient and effective ways (Lin et al. 2011). Besides, the requirement of the real-time routing also calls for a decentralized intersection control. Thus the local intersection control becomes essential to meet the above requirements. However, to reduce the AGV congestion in the whole system cannot simply be achieved by adopting the local control. The corresponding coordination mechanism among the local intersections should also be established. Therefore, the control strategy in this study is to locally control each intersection to generate the real-time routing decisions and meanwhile coordinate these intersections throughout the network to reduce the overall congestion.

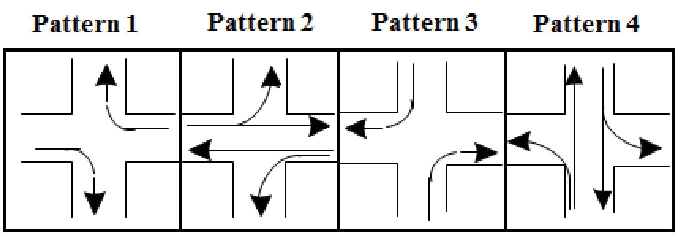

Figure 3: Sample movement pattern configuration

Since the current technology allows the real-time detection of AGV location, the local intersection control becomes a practical and applicable strategy to guide the AGVs efficiently to pass the intersection. To reduce the congestion in the local intersection, the certain control rules like virtual “traffic light” are set. These rules include how to form the movement patterns (see Fig 3), how to decide the duration of each pattern and how one pattern transits to the other (see Fig 4), which are all considered as decision variables determined by a mathematical model.

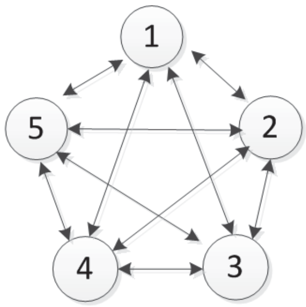

Figure 4: Possible pattern transitions

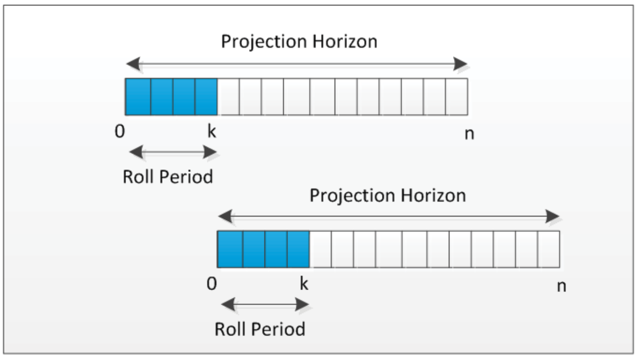

Figure 5: The rolling horizon approach

The main focus in the stage 2 is to develop a model-based optimization control strategy, which features a rolling horizon approach for traffic control. Rolling horizon concept used here attempts to take the future traffic around the intersection into consideration so that the model can be predictive. That is to say the coordination among the different intersections can be involved in this optimization model. For a given projection horizon with n intervals, head portion of horizon (from 0 to k interval, see Fig 5) is the period over which the arrivals of AGVs approaching the local intersection can be accurately obtained and the tail part where the future arrivals of AGVs to the intersection are predicted. The optimal rules are calculated for the whole horizon including the patterns, their lengths and sequence. To minimize the performance measures, such as AGV delays or makespan can be the objectives of the model.

2.4. Simulation Model

To demonstrate the performance of the proposed two-stage approach which integrates the global layout optimization and local intersection control, it should be applied on a simulation model simulating a large size container terminal which is subject to various practical operation demands. In the model, the specific module is established as the local intersection controller. To handle the complexity of connecting the two stages and applying the proposed optimization model and heuristics, the simulation model has defined a series of trigger events and introduced a few indicators helping determine whether the requirement is met to trigger certain events. The performance is compared with that attained by using other control rules, such as first-in-first-out or priority first or fixed pattern length and sequence. The whole simulation written in the C# with Visual Studio is scalable by allowing the extension of the network and the number of AGV, which provides a very useful way to verify the effectiveness of proposed approach.

3. Preliminary Result

The current preliminary experiment is only conducted to demonstrate the computational performance of the proposed global path design algorithm (algorithm 1) and the local control algorithm (algorithm 2) in three different network layouts. The overall performance of the two-stage approach should be verified by the simulation model which now is in progress. The current result shows that on the same layout the computational time for both algorithms has an increase when the number of jobs becomes larger from 20 to 100. But the increase in computational time for algorithm 1 is larger than algorithm 2, which indicates the number of jobs have more influence on algorithm 1 rather than algorithm 2. This can be explained by the fact that the algorithm 1 does globally optimization with all the jobs considered and algorithm 2 just takes the number of AGVs approaching the local junction into account. As for the effect of terminal size on the performance of two algorithms, it is similar to the effect brought by job number. With the terminal size larger, the computational time of algorithm 1 has a much more increase than algorithm 2, which can be explained in a similar way. Due to the time limit, the test case is not sufficient by considering more jobs and larger size terminal. The overall performance of two-stage approach is also not obtained currently from the simulation. Therefore, in next research phase we will explore how the computational time changes with greater job number and larger terminal size. Meanwhile, the simulation model will be used to verify the effectiveness of the proposed algorithms.

4. Roadmap

The preliminary result has shown that the two-stage algorithm is promising to solve the original large-scale problem efficiently. On basis of this decomposed algorithm, the proposed approach with its unique formulation and solving structure will furtherly improve computational efficiency and achieve a higher performance. Next the algorithms will be tested and compared for large scale instances and then the effectiveness of the proposed algorithms can be verified in the simulation model.

References

Bagchi, T. P. (2001). Pareto-optimal solutions for multi-objective production scheduling problems. *In Evolutionary multi-criterion optimization* (pp. 458-471). Springer Berlin Heidelberg.

Corréa, A. I., Langevin, A., & Rousseau, L. M. (2007). Scheduling and routing of automated guided vehicles: A hybrid approach. *Computers & Operations Research*, 34(6), 1688-1707.

Desaulniers, G., Langevin, A., Riopel, D., & Villeneuve, B. (2003). Dispatching and conflict-free routing of automated guided vehicles: An exact approach. *International Journal of Flexible Manufacturing Systems*, 15(4), 309-331.

Gawrilow, E., Köhler, E., Möhring, R. H., & Stenzel, B. (2008). Dynamic routing of automated guided vehicles in real-time. In Krebs, & Jäger, (Eds.), *Mathematics Key technology for the future* (pp. 165–177).

Langevin, A., Lauzon, D., & Riopel, D. (1996). Dispatching, routing, and scheduling of two automated guided vehicles in a flexible manufacturing system. *International Journal of Flexible Manufacturing Systems*, 8(3), 247-262.

Lin, S., De Schutter, B., Xi, Y., & Hellendoorn, H. (2011). Fast model predictive control for urban road networks via MILP. *Intelligent Transportation Systems, IEEE Transactions on*, 12(3), 846-856.

Nagar, A., Haddock, J., & Heragu, S. (1995). Multiple and bicriteria scheduling: A literature survey. *European journal of operational research*, 81(1), 88-104.

Qiu, L., & Hsu, W. J. (2000). Routing AGVs on a mesh-like path topology. In Intelligent Vehicles Symposium, 2000. IV 2000. *Proceedings of the IEEE* (pp. 392-397). IEEE.

Qiu, L., & Hsu, W. J. (2001). A bi-directional path layout for conflict-free routing of AGVs. *International Journal of Production Research*, 39(10), 2177-2195.

Zeng, J., & Hsu, W. J. (2008). Conflict-free container routing in mesh yard layouts. *Robotics and Autonomous Systems*, 56, 451–460.

Deadlock and Collision Prevention Routing for AGV in Large Scale System

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Extended abstract submitted for presentation at the
6th International Conference on Logistics and Maritime Systems (Sydney, 21-23 June, 2016)

1. Introduction

Automated Guided Vehicles (AGVs) have been deployed widely to replace the human beings in the container terminals, such as the Euromax terminal as Figure 1 in Rotterdam. Compared to the traditional truck system, the AGV system could reduce the operation cost, especially for the space-constrained ports and high labor cost ports. Therefore, as one of the busiest transshipment terminal, Singapore port plans to implement the AGV system from the quayside to the yard side in its latest terminal.

There has been extensive research on the AGV system in the container terminal. Kim (2006) proposes a graphical reservation method that use priority table to maintain priority consistency between the grid blocks therefore to avoid deadlock. However, just as the other small zone control approach (Yeh and Yeh, 1998; Guan and Moorthy, 2000; Lee and Lin, 1995), the algorithm has a difficulty in routing large number of AGVs. Gawrilow has proposed both static approach (2008) and dynamic approach (2007) to route the AGVs and guarantee deadlock avoidance. However, the static approach is only suitable for low and medium traffic flow and the dynamic approach requires precomputations of routes every time delay or other disturbance happens. Therefore, efficient deadlock-and-conflict-free routing algorithm, which could be applicable to the real world large AGV system without large computation time, is expected.

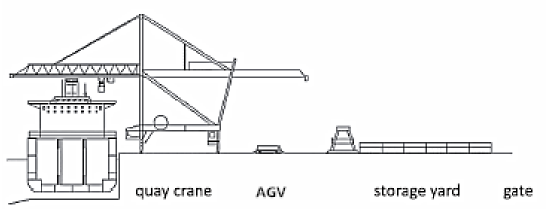

Figure 1: Container Terminal Layout

The objective of our research is to present an effective AGV routing algorithm which could prevent deadlock and collision for the large-scale system. We also attempt to minimize the overall travel time of the AGVs. The proposed algorithm is a two-stage algorithm which divides the routing into two levels: the high level, which provides the overall vehicle routing to avoid congestion, and the low level, which provides detailed scheduling to avoid deadlocks. The two stages are interrelated and work together to find the shortest time and deadlock-collision-free route in real time.

The separation of the two stages reduces the size of the problem and makes it suitable for the large-scale problem. It also reduces the communication between AGVs and the central controller, therefore reduces the computation time. What's more, the AGVs are more flexible to change the routes.

The remaining parts are organized as follows: Section 2 introduces the deadlock-free routing problem and a two-level routing algorithm is proposed. Some preliminary results and simple test cases are shown in Section 3. Finally, conclusions and future works are outlined in the last section.

2. Methodology

Our work starts after the AGV dispatching work, each AGV is assigned to different job and the corresponding start time, start and end location are known. Based on these information, a two level routing and traffic control algorithm is proposed. After dividing the overall layout into zones, the high level routing aims at reducing congestion in each zone and the low level, inner zone scheduling level targets at avoiding deadlock and collision inside each zone. An overview of the methodology in our study is shown in Fig 2.

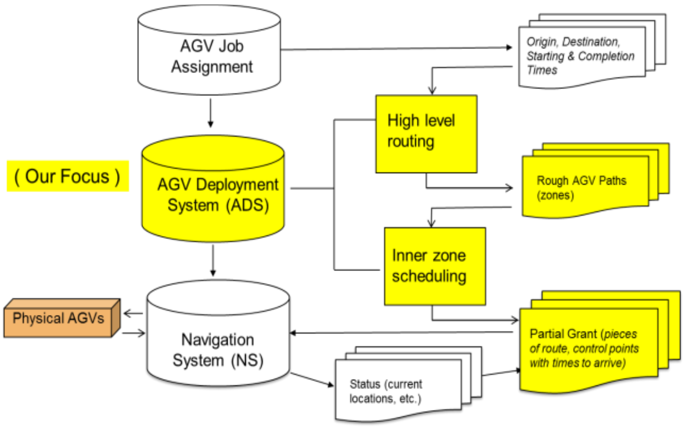

Figure 2: Outline of the Two-stage Approach

2.1 High level routing

The overall layout of the container terminal is divided into zones as Fig 3 which can hold more than one AGV, such as straight lane zones (2, 6 etc.), intersection zones (11), T shape zones (9, 13 etc.) and L shape zones (1, 17 etc.). The main objective of the high level routing stage is to determine the routes of the AGVs in terms of the zones they will travel to fulfill their task. At the same time, the congestion can be minimized.

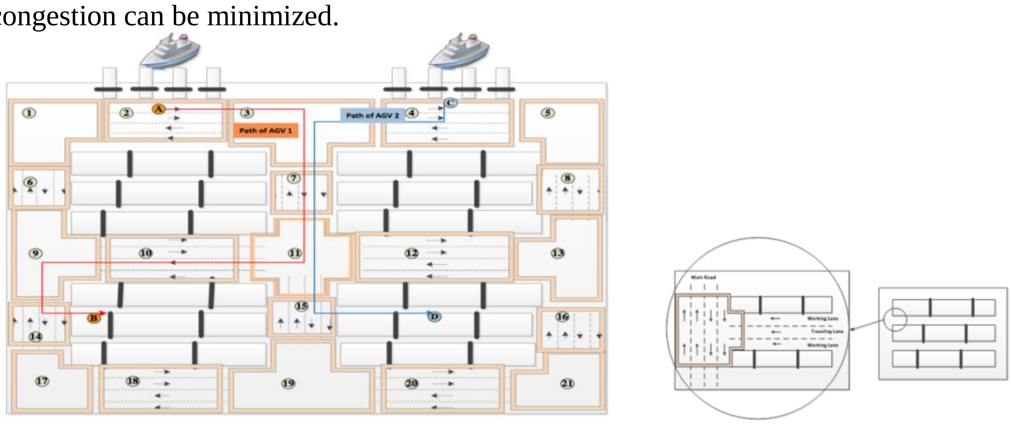

Figure 3: Layout of the Terminal

Once the arrival rate information is known, we can route the AGVs based on the delay proportion and delay to duration ratio inside each zone. The steps will be as follows:

Step 1: Generate the zone sequence for all AGVs.

Step 2: Evaluate the congestion status by checking the overlapping within each zone (such as the number of AGVs or the arrival rate)

	zone m_1	......	zone m_k	......
AGV k_1	√		√	
AGV k_2	√	√	√	
......		√	√	
AGV k_n	√		√	√
......			√	

Too many overlapping means congestion.

Step 3: Based on the congestion status to route the AGVs.
The advantage of the high level routing is to avoid the congestion in the same zone. At the same time, it can control the total number of AGVs inside one zone; therefore reduce the computation needs and possible deadlocks in the inner zone scheduling stage.

2.2 Inner zone scheduling

We divide the roads inside the zone into a set of control points and two control points link a segment as Figure 4 in straight lane zones, and the intersection zones are the same as Figure 5. Each segment is reserved only by one AGV. And if one segment is used, all the conflict segments (segments which share same start or end control points or have an intersection) will be blocked. If conflict or deadlock happens in one segment, the later entering AGV into the segment will be delayed. The ratio of delay time and travelling duration inside the zone and delay proportion given a set of vehicle arrivals can be used as parameters to test our heuristics.

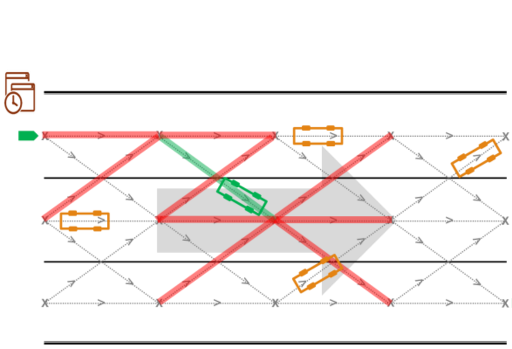

Figure 4: Straight Lane Zone

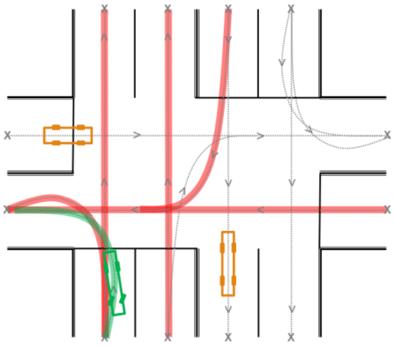

Figure 5: Intersection Zone

We propose a MIP model, a branch and bound methods and two heuristics to find the optimal routes inside the zone. Different approaches have different advantages and disadvantages. Based on different situations, we should choose the approach which could tradeoff between the optimality and computation time.
The inner zone scheduling stage is mainly aimed at determining the segments the AGVs take inside the zone based on the information from the high routing level (enter time of the zone and the possible exit segments). Each zone will schedule for all the AGVs inside it about whether they should change lane, accelerate or decelerate to avoid deadlock and collision while minimize the travelling time. For the intersection zone, it also decides how to make turns and the lane the AGV to enter into, which will be the turning profile for the AGV.

3. Results

Firstly, we test relationship between the delay proportion and delay to duration ratio using simulation. As the convergence trend shown by Fig 6 and Fig 7, a simulation run length of 2000 scheduling jobs is shown to be sufficient to produce a representative data set. Then we find the relationship between the arrival rate and the two parameters, just as Fig 8 and Fig 9. These information can be used in the high level routing MIP model and find the routes from zone to zone for the AGVs.
For the inner zone scheduling stage, the branch and bound method can find the global optimal. However, the computation time increases a lot with the number of AGVs inside the zone. Therefore, we use it as a benchmark and compare the different heuristics as Fig 10. We find that the modified Dijkstra's algorithm could find the near-global-optimal results in shorter time. Therefore, it can be used in the real-time control of the AGVs inside the zone.
This study innovatively combines the AGV routing and the traffic control to provide a solution to large-scale problems. To be specific, routing inside the zone other than in the overall layout reduces the problem size. Moreover, the parallel routing inside different zones reduces the computation time. Lastly, the two-stage algorithm can reduce the possible congestion and deadlock.

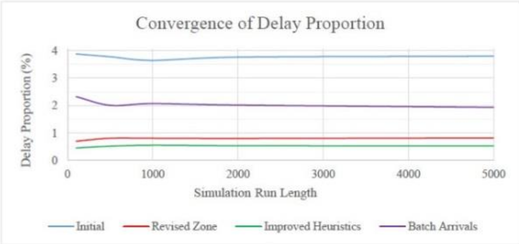

Figure 6: *Convergence of Delay Proportion*

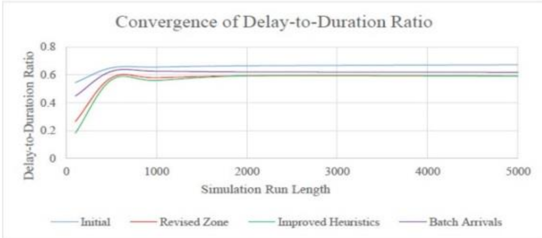

Figure 7: *Convergence of Delay to Duration Ratio*

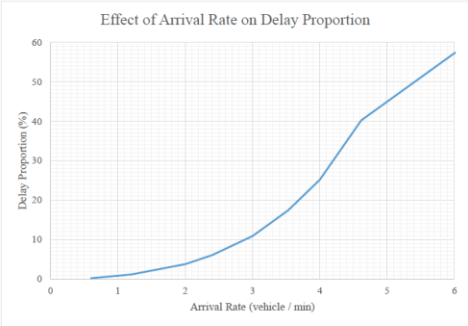

Figure 8: *Delay Proportion*

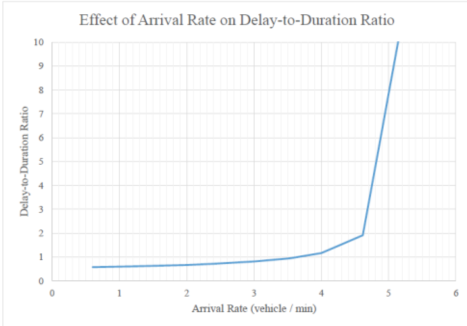

Figure 9: *Delay to Duration Ratio*

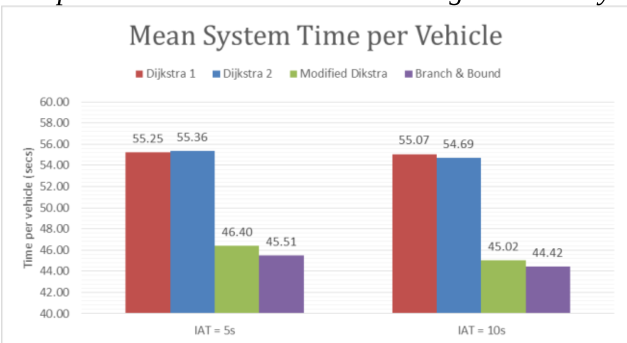

Figure 10: Comparison of Different Heuristics

4. Future Research

Currently, the basic structure of two individual stages has been formulated and the preliminary results indicate that each stage performs well. Since our project is still in progress, the remaining work, such as the test of the integration of the two stages and the optimization of the current zone size and segment size, are about to achieve better performance in terms of computation time and objective value. Other research such as the test of new heuristic methods and the optimization of the dispatching of AGVs are also promising research areas.

References

Gawrilow, E., Köhler, E., Möhring, R. H., & Stenzel, B. (2008). *Dynamic routing of automated guided vehicles in real-time* (pp. 165-177). Springer Berlin Heidelberg.

Kim, K. H., Jeon, S. M., & Ryu, K. R. (2006). Deadlock prevention for automated guided vehicles in automated container terminals. *Container Terminals and Cargo Systems*, 243-263. Springer Berlin Heidelberg.

Klimm, M., Gawrilow, E., Möhring, R. H., & Stenzel, B. (2007). Conflict-free vehicle routing: load balancing and deadlock prevention. *Technical Report*, 2007.

Lee, C. C., & Lin, J. T. (1995). Deadlock prediction and avoidance based on Petri nets for zone-control automated guided vehicle systems. *International journal of production research*, **33**(12), 3249-3265.

Moorthy, K. M. R. L. (2000). Deadlock prediction and avoidance in an AGV system (Doctoral dissertation, SINGAPORE-MIT ALLIANCE).

Yeh, M. S., & Yeh, W. C. (1998). Deadlock prediction and avoidance for zone-control AGVS. *International Journal of Production Research*, **36**(10), 2879-2889.

11:00 – 12:00	Session 7A (Floor 17)	Chair: Kap Hwan Kim
	Theme: Industrial Session 2 (Automation in Container Terminals)	

Determination of AGV Lane Directions in an Automated Container Terminal for Optimal Traffic Flow
Taekwang Kim and Kwang Ryel Ryu

A Simulation Study of the Operation for an Automated Container Terminal with Overhead and Floor Rails
Jeong Hoon Seo, Xuefeng Jin, Kap Hwan Kim and Byung-Nam Kim

Determination of AGV Lane Directions in an Automated Container Terminal for Optimal Traffic Flow

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Extended abstract submitted for presentation at the
6th International Conference on Logistics and Maritime Systems (Sydney, 21-23 June, 2016)

1. Introduction

In this paper, we address the problem of traffic control for automated guided vehicles (AGV) in an automated container terminal (ACT) where AGVs transport containers between the quayside and the storage-yard blocks. When all the drive lanes are bidirectional, it will be the router that should be responsible for minimizing traffic congestion by finding a good route for each AGV. However, the routes found by the existing routing algorithms are not optimal because they find the routes only one at a time. While a route found for a current AGV can be claimed as an optimal one given the routes of all the previous AGVs, it is only the result of a greedy decision-making unless the routes for many or all of the future AGVs are taken into account simultaneously. Choe et al. (2010) showed that the traffic flow of AGVs resulting from using a greedy router can be improved by setting some of the lanes as unidirectional in a perpendicular-type ACT where the storage blocks are laid out perpendicularly to the quay and the operation of AGVs is restricted to the apron area. What we propose in this paper is an extension of their work to a horizontal-type ACT where the storage blocks are laid out in parallel to the quay and the AGVs can travel not only in the apron area but also to all the pathways in-between the storage blocks.

2. Proposed Method

We assume that we are given the berth plan for the future vessels within a certain time horizon as well as the space allocation plan at the storage yard for the containers of those vessels. An optimal setting for the lane directions can then be searched for by using a genetic algorithm with the objective function of minimizing the standard deviation of the unit-time AGV traffic volumes on all the lanes to transport those containers. To evaluate a candidate lane-direction setting, the traffic volumes on each lane in regular unit-time intervals are roughly estimated by simulating only the loaded travels of AGVs to transport all the containers in the horizon. In this simulation, the AGVs are assumed to travel at a constant average speed following the shortest-distance routes and deadlocks as well as collisions are all ignored to alleviate the computational burden.

3. Results and conclusions

The results of AGV simulation experiments using a shortest-time routing algorithm together with the earliest-deadline-first dispatching heuristic show that the lane-direction setting found by the proposed method brings about better traffic flow than the ordinary all bidirectional setting.

References

Choe, R., Kim, H., Park, T., and Ryu, K. R. (2010) Dynamic adjustment of the traffic flow of AGVs in an automated container terminal, *Proceedings of the 10th IASTED International Conference Artificial Intelligence and Applications (AIA 2010).*

A simulation study of the operation for an automated container terminal with overhead and floor rails

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Extended abstract submitted for presentation at the
6th International Conference on Logistics and Maritime Systems (Sydney, 21-23 June, 2016)

1. Introduction

Over the recent years, the use of containers for intercontinental maritime transport has been dramatically increased (Günther and Kim, 2006). Amount of cargo transportation among nations by containers has become very popular and come with many challenges. In a review paper by Steenken, et al. (2004), many operational issues in a container terminal are described, which include berth allocation, stowage planning, quay crane scheduling, and yard crane scheduling. Most of container terminals have devoted much effort for improving the efficiency of container terminals by applying new operation strategies and handling technologies.

During the last decade, a growing number of ports decided to automate a part of or entire operations in terminals. Various types of automation technologies have been developed in quay area, apron area, yard storage area, and gate. In addition, more and more mega vessels, larger than 15000 TEU, are being deployed to main routes of trades. Note that the high throughput capacity must be provided to perform all the required number of ship operations within satisfactory time even for mega vessels. However, many container terminals are not efficient enough to perform loading and discharging operations within the required service time. And in order to overcome the limitation in the throughput capacity of current automated container terminals, several new conceptual automated container terminals have been suggested.

This paper suggests a new conceptual automated container terminal with overhead and floor rails for which a simulation program is developed to test various design alternatives. This study discussed various operation rules for an automated container terminal (ACT) with overhead and floor rails.

Figure 1 show a new type of ACT in which a floor rail based transport system, called flatcar system (FCS) is used to transport containers between quay cranes and the storage yard and in the yard storage area, an overhead shuttle system (OSS) is used. In the OSS, overhead shuttles travel over the storage yard underhung the vertical mono-rails installed over the storage yard.

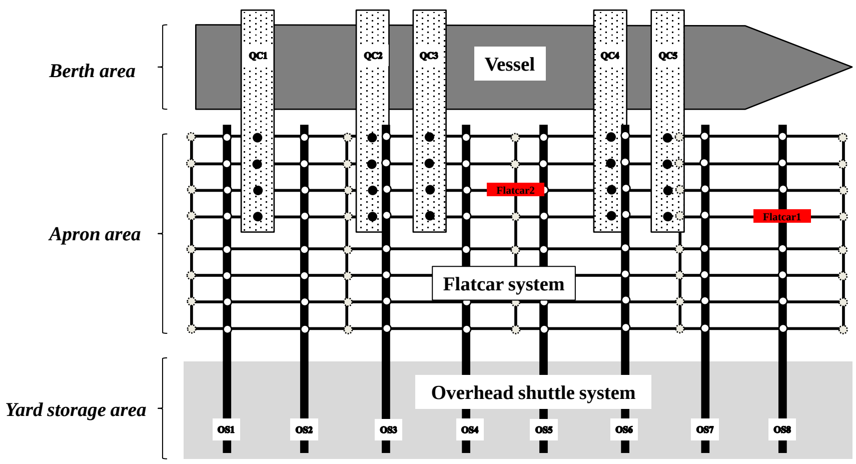

Figure 1: Automated container terminal with overhead and floor rails

2. A simulation program

For this study we developed a simulation model by using an Object-Oriented (OO) simulation tool, called Plant Simulation. Plant simulation is a process interaction language for discrete event simulation based on an OO language. Also the software provides the user with graphical interfaces to design all objects on the screen of framework. Because complex structures can be created very clearly on several (logic) layers by using this software tool, so we used this concept to design our simulation models. For this new conceptual ACT, a hierarchy structure is developed as shown in Figure 2.

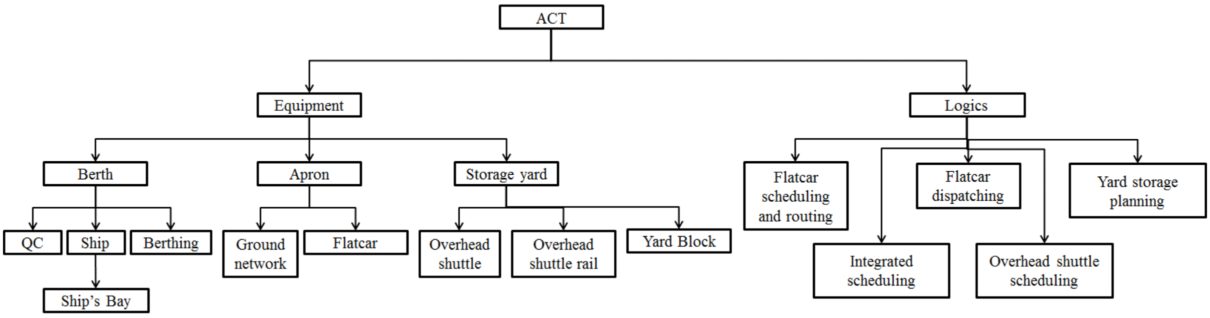

Figure 2: Hierarchy structure for new conceptual ACT

3. Operation scenario and rules

The handling system in this presentation performs the tasks that consist of the operation of loading, unloading, carry-in, and carry-out operations. Loading operation is decomposed into elementary activities such as lifting the export containers by the overhead shuttle in the storage yard, putting the containers onto the flatcars in the apron area, and finally placing them in the ship's bay by using the quay crane (QC). Unloading operation is performed in the reverse order to the loading operation.

Several operation rules are programmed in the simulation. They are yard storage planning, flatcars dispatching, flatcars scheduling and routing, overhead shuttle scheduling, and integrated scheduling for all types of equipment.

Yard storage planning: it attempts to distribute containers over nearby yard rails. The positions of containers are directly related to the performance of loading and unloading operations. The rules determine import container positions when performing unloading operation and export container positions when performing carry-in operation.

Flatcars dispatching: in the simulation system, it is described that several QCs and more than 4 flatcars for each QC perform loading and unloading operations together at the sane time. Dispatching rules attempt to match a QC task and a flatcar with the objective of minimizing the turnaround time of a vessel. The dispatching rule is programmed in the simulation system for assigning flatcars to QC tasks.

Flatcar scheduling and routing: for efficiently operate FCS, flatcar scheduling and routing algorithm is very impotent. Various rules for scheduling and routing for flatcars are implemented in the program for performing delivery tasks efficiently and avoiding deadlocks and the conflict among flatcars.

Overhead shuttle scheduling: overhead shuttles (OS) are used for moving and storing containers in the bock stacking storage yard. The simulation system describes various OS operations such as loading, unloading, carry-in, carry-out, rehandling, and re-marshalling. Assigning tasks to OS and scheduling OS operations are key issues for the efficient operation of the OS system. The rules for the OS operation are programed in the simulation system.

Integrated scheduling for all types of handling equipment: the list of ship operations are delivered from the operation planning system and a ship operation is decomposed into a task for QC, flat car, and an OS. A carry-in operation is decomposed into a task for an OS and a road truck. One important issue is how make different types of equipment synchronized with each other. A rescheduling method must be provided for the case where a piece of equipment cannot perform a task within a scheduled time window.

4. Conclusions

This study proposes a simulation model for the automated container terminal (ACT) system which is developed using an object-oriented (OO) approach and Plant-Simulation. For analysing the performance of the new conceptual container terminal system, we constructed a simulation model in which many operation logics and the performance measures for the ACT are provided. As a future study, it is necessary to verify and validate the developed simulation model for the ACT. This simulation program may be used for improving the design of the ACT and various operation rules in the model.

References

Günther, H. O. and Kim, K. H. (2006) Container terminals and terminal operations. *OR Spectrum*, **28**(4), 437-445.

Steenken, D., Voß, S. and Stahlbock, R. (2004) Container terminal operation and operations research- a classification and literature review. *OR spectrum*, **26**(1), 3-49.

http://en.wikipedia.org/wiki/Plant_Simulation.

Legato, P. and Mazza, R. M. (2001) Berth planning and resources optimisation at a container terminal via discrete event simulation. *European Journal of Operational Research*, **133**(3), 537-547.

Yun, W. Y. and Choi, Y. S. (1999) A simulation model for container-terminal operation analysis using an object-oriented approach. *International Journal of Production Economics*, **59**(1), 221-230.

Thiers, G. F. and Janssens, G. K. (1998) A port simulation model as a permanent decision instrument. *Simulation*, **71**(2), 117-125.

Ballis, A. and Abacoumkin, C. (1996) A container terminal simulation model with animation capabilities. *Journal of Advanced Transportation*, **30**(1), 37-57.

Yang, C. H., Choi, Y. S. and Ha, T. Y. (2004) Simulation-based performance evaluation of transport vehicles at automated container terminals. *OR Spectrum*, **26**(2), 149-170.

11:00 – 12:00	Session 7B (Floor 16)	Chair: Xiaowen Fu
	Theme: Maritime (Carrier Alliances, port connectivity and Maritime transport Policies)	

Emission Charge and Liner Shipping Network Configuration- An Economic Investigation of the Asia-Europe Route
Wayne Lei Dai, Xiaowen Fu, Tsz Leung Yip, Hao Hu and Kun Wang

Potential Impacts of International Maritime Transportation Policies on the Pacific Region: A Case Study in Melanesia
Yu Lu, Ryuichi Shibasaki and Hironori Kato

Emission charge and liner shipping network configuration

- an economic investigation of the Asia-Europe route

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1. Introduction

Despite the high fuel efficiency of modern ships, the large volume of commodity trade and the rapid growth of the maritime industry make international shipping a major source of carbon emissions. Emissions from the global maritime sector currently account for about 3% of global emissions, and are expected to reach 5% in 2050 (European Commission, 2013). The container shipping sector is of particular importance in the maritime industry. Psaraftis and Kontovas (2009) noted that although container ships accounted for 4% of all vessels, they generated 20% of emissions from international shipping in 2007. With continued growth expected in the sector, reducing greenhouse gas (GHG) emission from maritime shipping has been a key challenge to organizations and governments around the world.

This study aims to contribute to such policy discussions by modeling the effects of imposing emission charges to the maritime sector, with a focus on shipping networks configuration and the associated implications to ports and regional economies along shipping routes. We consider the case when a regional EU emission charge or equivalently a fuel tax is introduced to shipping activities within EU and trips to/from EU ports. Our modeling results for the Asia-Europe route suggest that liner network configuration is influenced by emission charge, fuel price, port loading/unloading cost, and demand pattern of cargo transport across different markets. If emission charge is introduced and if the charge is above a threshold, carriers will reconfigure their shipping networks and thus significantly influence the revenue, connectivity and competitiveness of major ports along the Asia-Europe routes.

2. Economic model

We consider the container shipping market between Asia and Europe. Since numerous manufacturing bases are located in China, Japan and Korea, Northeast Asia (NE Asia) accounts for a large share of the container traffic to Europe. Trans-Oceanic ships are used to serve major NE Asian ports such as Shanghai, Tsingtao, Busan, Tokyo, and in many cases also Hong Kong and Shen Zhen. These large ships often call the Port of Singapore on their way to Europe, where cargos from Southeast Asia (SE Asia) are consolidated and loaded. For intra-oceanic transport from SE Asia to Singapore, cargos are typically carried with smaller ships. Such a shipping network is illustrated in Figure 1, in which routes served by trans-oceanic ships are presented with large block arrows, whereas routes served by small intra-oceanic ships are presented with solid arrows. Regions are numbered from 1 to 5 for ease of notation, thus that the traffic volume from NE Asia (Area 1) to Europe (Area 5) can be denoted as q_{15} for example.

With the introduction of EU emission charge or fuel tax, carriers are likely to respond strategically in order to alleviate the impacts. Without loss of generality, we consider the case of Dubai which is a leading port in the region but our results should hold if any other port in North Africa or Middle East is considered. Among the possible options, following representative cases are considered in our study:

- Case I—Status Quo: There is no change in the configuration of shipping network. A trans-oceanic ship from NE Asia calls Singapore on its way to Europe.
- Case II—Shifting Hub to Dubai: The consolidating hub is shifted from Singapore to Dubai. Trans-Oceanic ships are used as feeder services for cargos from NE Asia while smaller intra-Oceanic ships are used as feeder service for cargos from SE Asia.
- Case III—Shifting Hub to Dubai with intra-Oceanic Feeder only: Dubai is used for cargo consolidation. All feeder services from NE Asia and SE Asia are offered by small intra-Oceanic ships.

3. Methodology

This section explains the modeling details for the calculation of shipping costs, trans-shipment costs and emission charges. These calculations are necessary for the modeling of shipping companies' operational strategies when an EU emission charge is introduced.

To model shipping firms' operational details in the Asia-Europe route, the following specifications are used. It has been estimated that the average fuel consumption of marine ships is approximately proportional to the cube of vessel speed. Corbett et al. (2009) concluded that CO_2 emission is proportional to fuel consumption. The emission volume measured in kilogram can be obtained by multiplying fuel's carbon fraction (86.4% for typical bunker fuel) and a factor for converting carbon to CO_2 (equal to 44/12), and fuel consumption. Capital and operating cost of contain shipping can be influenced by many factors such including the type of ship used, insurance policy, repair and maintenance schedule etc. This cost category refers to loading / unloading cost and associated expenses (e.g. warehousing) at a port.

With the above model specifications, shipping carriers' optimal operational strategies under alternative network configurations can be outlined as follows. The benchmark case denotes the case without fuel tax, a carrier's profit maximization problem is defined, where the fuel price is without emission charge / fuel tax. The profit function can be thus specified in terms of the distance between ports, and cruising speeds along different shipping routes are carriers' decision variables. When emission charge is imposed in case I, II and III, the effective fuel price is defined such that the bunker price increases, an equivalent fuel tax increases due to emission charge. The profit maximization problems of a shipping carrier in different cases are specified. The optimal cruising speed in our model is determined by vessel size and fuel price. The total emission volumes for carrying cargoes from Asia to EU are calculated. With the analytical solutions obtained, we can use real industry data to calibrate our model, so that the market outcomes in real markets can be simulated.

4. Model Calibration and Simulation

We calibrate our model with container operation data in 2007 in the Asia-Europe route. When fuel emission charge is imposed, shifting trans-shipment activities from Singapore to Dubai will lower emission charges paid by shipping lines, but will increase trans-shipment cost due to loading/unloading operations at a port. A shipping line's profit under different network configuration can thus be regarded as a function of the fuel emission charge equivalent fuel tax $\chi = \lambda_1 - \lambda_0$, and the loading/unloading cost l_s and l_d. We set the benchmark loading cost in Singapore and Dubai as USD 15 per TEU, and the profits for the three cases can be calculated for different fuel tax values.

5. Conclusion

This paper models shipping lines' operational costs and CO_2 emissions under alternative geographic network configurations when an emission charge, or equivalently fuel tax, is imposed on operations from Asia to Europe. Three possible shipping networks are modeled and calibrated with real industry data. Extensive sensitivity tests are subsequently carried out on key assumptions to validate the robustness of simulation results and to examine the effects of various influencing factors. Our modeling results suggest that shipping firms' network configuration is influenced by emission charge, fuel price, port loading and unloading cost, and demand pattern of cargo transport across different markets. Total emission will be reduced by an EU emission charge scheme. However, if the charge is above a threshold, carriers will reconfigure shipping networks to minimize their costs including emission charge payments. This will offset part of the emission reduction achieved by the emission scheme. As a result, a higher charge does not always lead to a higher emission reduction. In addition, the performance of major ports along the Asia-Europe routes will be influenced in different ways, leading to conflicting views from regional countries since some will benefit economically and others lose due to such a policy. These findings reveal possible market distortions associated with regional emission systems, and highlight the complex effects of international environmental policies when market dynamics are considered.

<Full paper available upon request>

Potential Impacts of International Maritime Transportation Policies on the Pacific Region: A Case Study in Melanesia

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1. Introduction

The Pacific region consists of numerous islands dispersed in the southwest of the Pacific Ocean. Its remoteness from the world's major markets has led to higher trade costs, and the dispersed nature of the region has also led to transportation services being expensive. Such geographical disadvantages have hampered the economic development of Pacific Islands (PI) (ADB-ADBI 2015). As international shipping in the Pacific region relies heavily on maritime transportation and over 80% of regional international cargo in tonnage basis is transported by sea transportation (WTS 2013), an efficient maritime transportation system is one of the critical issues for regional economic growth.

In the PI region, Melanesia is a relatively developed area. It consists of Papua New Guinea, Solomon Islands, Vanuatu, Fiji, and New Caledonia, and among these islands, a sub-regional organization named the Melanesian Spearhead Group (MSG) was established in 1988. MSG envisions itself as a leader group within the PI region and aims to support the development of its members and the entire region. Raising efficient movement of goods and improved intra-regional connectivity as key priorities, MSG is working on the commencement of a new shipping service among its members. However, according to our interview with MSG in September 2015, financial management is a critical potential risk for the new service. Thus, it may be necessary to incorporate the private sector by distributing subsidies, which is the case in many other shipping services in the region.

ADB (2007) points out that, in general, such direct government involvement in the provision of shipping services has been costly and failed to produce efficient and reliable services. Although the Pacific Forum Line (PFL), which is still in operation today, is raised as an exception, the study mentions that success came only after some painful lessons. In pursuit of their goal to provide improved services to PI, PFL's port coverage and service frequencies well exceeded commercially justifiable standards, resulting in major financial straits. The recent success of PFL is largely attributable to its focusing on larger PI and profitable services. As this example indicates, commercial viability is a major constraint for such attempts in reality.

Given this, our study aims to examine how the private sector should be incorporated into the maritime sector in the PI region. However, due to the poor availability and reliability of even the most basic data (ADB 2007) and the lack of an adequate analysis tool, existing studies are rather qualitative than quantitative despite the latter approach being crucial in discussing the potential impacts of policies. An earlier study by the authors (Lu et al 2016) modifies the simulation model for international cargo flows in the world originally presented by Shibasaki and Kawasaki (2016) so that it is applicable to the PI region. This study utilizes this model in order to pursue the aim stated above.

2. Model overview

The model presented by Lu et al (2016) simulates container movements on an international maritime shipping network highlighting the Pacific region based on the existing method proposed by Shibasaki and Kawasaki (2016). The model assumes the user equilibrium principle in network assignment considering the vessel capacity with the shipping demand between ports as given. Each container, which is defined on a TEU (twenty-foot equivalent unit) basis, is transported using the route with the minimum total transit time, including the congestion time, from an origin port to a destination port. In the model, major shipping companies transport international maritime containers in the world whereas local shipping companies transport them in the Pacific region. The maritime shipping network in the model covers local ports in the Pacific region in addition to the world's major ports that have container handlings of over 500,000 TEU as of 2013. For model calibration, a TEU-basis inter-port Origin-Destination (OD) matrix was prepared including estimations of OD flows to, from, and among PI using available data sources. Then unknown parameters in the model were calibrated to fit estimated rates and volumes of transshipment to those observed at major hub ports in the world and two major ports in the PI region whose data was available, namely, Suva (Fiji) and Apra (Guam).

Figure 1 shows the comparison between the estimated and the observed transshipment rates at the world's major hub ports based on data for the year 2013. The total throughput of transhipped containers estimated for all ports in the model is 98.8 million TEU, while the observed throughput is 99.8 million TEU. This observation and Figure 1 indicate that the model reproduces maritime container flows in the world reasonably well.

Table 1 shows the estimated versus the observed annual volumes and rates of transshipment at major Pacific ports. The estimated result that these ports have relatively larger amounts of transshipment is consistent with existing literature and information collected by the authors through a field survey. The large underestimation observed at Apra may be caused by empty containers included in the observed data. The observed data for Auckland and Suva does not include empty containers.

Table 1: Estimated vs. observed volumes (TEU) and rates of transhipment containers at major Pacific ports

	Estimated		Observed	
Port	Volume	Rate	Volume	Rate
Brisbane (Australia)	191,663	25.7%	N.A.	N.A.
Auckland (New Zealand)	174,161	22.6%	173,404[a]	17.9%
Tauranga (New Zealand)	29,050	4.4%	N.A.	N.A.
Apra (Guam)	4,200	11.1%	42,000[b]	28.0%
Lae (Papua New Guinea)	7,929	9.0%	N.A.	N.A.
Suva (Fiji)	10,811	15.1%	11,007[c]	10.0%
Noumea (New Caledonia)	2,695	4.2%	N.A.	N.A.
Papeete (French Polynesia)	8,739	22.0%	N.A.	N.A.
Pacific Islands Total	35,856	6.0%	N.A.	N.A.

Source: a. Data acquired from Ports of Auckland (POAL); b. Jose D. Leon Guerrero Commercial Port of Guam Master Plan Update 2013 Report (Parsons Brinckerhoff 2013); c. data acquired from Fiji Ports Corporation; N.A. means that the data is not available.

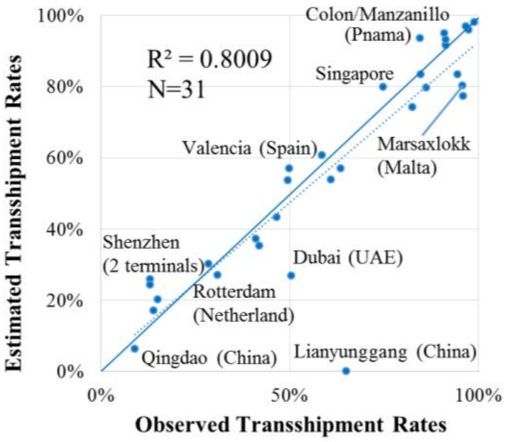


Figure 1: Estimated and observed transshipment rates at the world's major hub ports

3. Case study in Melanesia

Figure 2 illustrates the shipping network of container vessels in the PI region as of 2013, created from the Containership Databank (MDS Transmodal Ltd. 2013). Existing services are represented by blue lines and are categorized by their annual TEU capacity. The green line represents the service newly assumed in this study. Australian ports such as Brisbane and New Zealand ports such as Auckland and Tauranga as well as several PI ports such as Suva, Papeete, Noumea, and Lae are regional hub ports.

In this case study, the potential impacts of a new shipping service planned by MSG are examined with

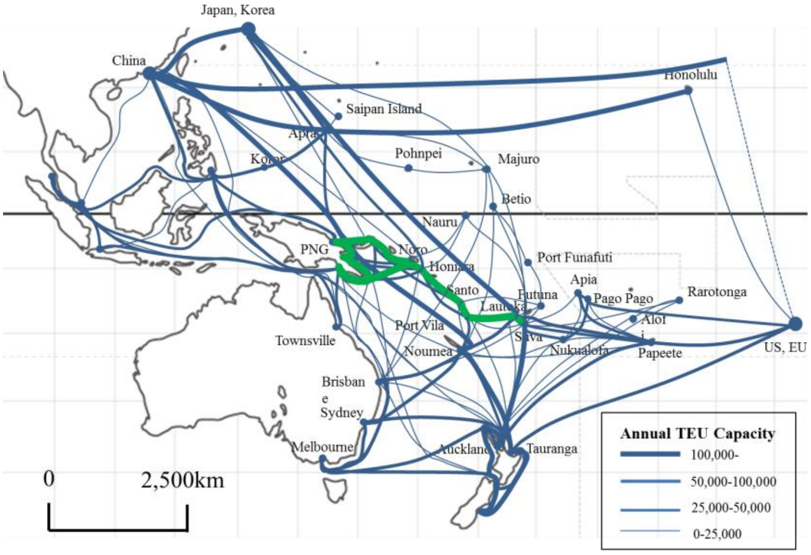


Figure 1: Maritime shipping network in the Pacific region as of 2013

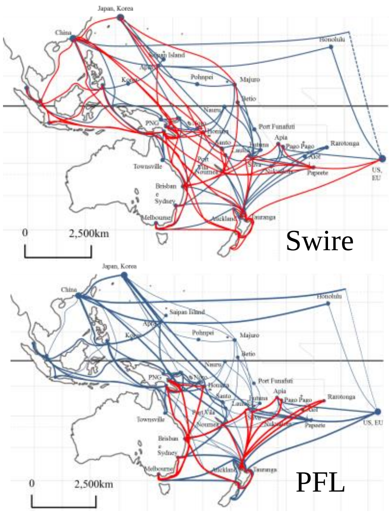


Figure 2: Shipping network of Swire and PFL in the Pacific region as of 2013

the model mentioned above, assuming that it is operated by different private shipping companies. Two scenarios are prepared for 2030: (1) the "baseline scenario"; and (2) the "MSG scenario", which assumes the commencement of the new shipping service in Melanesia in addition to the services assumed in the baseline scenario. Comparisons are made based on the weighted average shipping time for containers to and from PI ports AT_P (hour), which represents the efficiency of regional maritime transportation, and the load factor of the new service, which reflects the commercial viability.

Based on the results of our interview survey with MSG, the ports of call of the new service are assumed to be Suva, Lautoka, Port Vila, Santo, Honiara, Noro, Port Moresby, Lae, Madang, Rabaul, back to Noro, and then the return trip back to Suva in the reverse order. The vessel size of the new service is assumed to be the average of that of other services calling only at Australian, New Zealand, and PI ports, which is 734.7 TEU. Possible operators for the new service are selected based on the company's number of PI services and other relevant information collected from existing literature and through our field survey. As a result, companies with more than 5 PI services are selected.

Table 2 shows the selected operators and the number of their PI services. It also shows the improvements in the weighted average shipping time AT_P (hour) compared to the baseline scenario and the average load factor per shipping link of the new service when it is operated by each company. It is important to note that the model does not include empty containers and thus the load factor seems smaller than what one would expect. (This applies to Table 3 as well.) CMA-CGM and Swire show relatively high performances in both indices. This is due to the vast shipping network these two companies possess in the PI region. PFL shows a large improvement in the average shipping time as well, and this is because the new shipping service complements the existing shipping network of PFL, which connects PNG, Australia, New Zealand, and Polynesia without passing through Melanesia. (The shipping network of Swire and PFL are shown in Figure 2.) These results indicate that the operator's network characteristics significantly influence the new service's functionality.

However, the individual load factors shown in Table 2 are all below 5%, which may be considered unprofitable. Having multiple companies operate the new service is a possible approach for this problem. Here, it is assumed that the vessel capacity is equally divided among the operators. Table 3 shows the average load factor of the new service when it is operated by multiple companies. The partner companies are selected in the order of the number of their PI services (i.e. in the order of Swire, Matson, CMA-CGM, Sofrana, PDL, and PFL). The results indicate that more containers utilize the new service as more companies take part in the operation. When all 6 selected companies operate the new service together, the average load factor exceeds 20%. Although this number is smaller than the world average of 33.3%, the new service will have a better chance of being profitable. Table 3 also shows the sum of the individual load factors of each operator shown in Table 2. The average load factor is larger than these numbers in every case, and this indicates that more containers utilize the new service when it is jointly operated by multiple companies compared to when several services are operated individually. The above observations suggest that having multiple companies operate the new service is an effective approach for improving the commercial viability of the new service.

Table 2. Number of PI services, improvement in AT_P compared to the baseline scenario, and average load factor per shipping link of the new service by selected operators

	CMA-CGM	Matson	PDL	PFL	Sofrana	Swire
Number of PI services	6	8	5	5	6	11
Improvement in AT_P (hour)	1.7	-0.8	-0.3	1.2	0.1	1.0
Average Load Factor	4.1%	1.6%	1.8%	1.6%	1.8%	4.2%

Table 3. Average load factor per shipping link of the new service and sum of the individual load factors of the operating companies

	Number of Operators					
	2	3	4	5	6	World average
Average Load Factor	6.4%	12.5%	15.9%	17.6%	20.6%	33.3%
Sum of Load Factors	5.9%	9.9%	11.7%	13.4%	15.0%	-

5. Conclusion

This study examined the potential functionalities of a new shipping service in Melanesia by applying a model to simulate international cargo flows on a global scale with the emphasis on the Pacific region. The results indicate that the new service is more able to contribute to the efficiency of regional maritime transportation and also to welcome more containers when operated by companies with wide shipping connections in the Pacific region. The results also imply that more containers utilize the new service when it is jointly operated by multiple companies, leading to a higher commercial viability. These results are expected to contribute to discussing the incorporation of the private sector into the regional maritime transportation in the Pacific region.

One further issue of this study is the need to include shipping cost and freight charge in the model, not only the shipping time. By doing this, the profit for each shipping company can be calculated, allowing for further discussions. The development of a model to simulate the shipping companies' behaviour of structuring maritime shipping networks should also be considered as a possible next step.

References

Asian Development Bank (2007) *Oceanic voyages: Shipping in the Pacific*. Manilla.

Asian Development Bank and Asian Development Bank Institute (2015) *Pacific opportunities: Leveraging Asia's growth.* Manila.

Fiji Ports Corporation Ltd. (2015) Data acquired from interview survey.

IHS Inc. (2013) *World trade service*.

Y Lu, R Shibasaki and H Kato (2016) Potential impacts of international maritime transportation policies on the Pacific region. *6th International Conference on Transportation and Logistics (T-LOG 2016).* 7-9 September 2016.

MDS Transmodal Ltd. (2013) *The containership databank*.

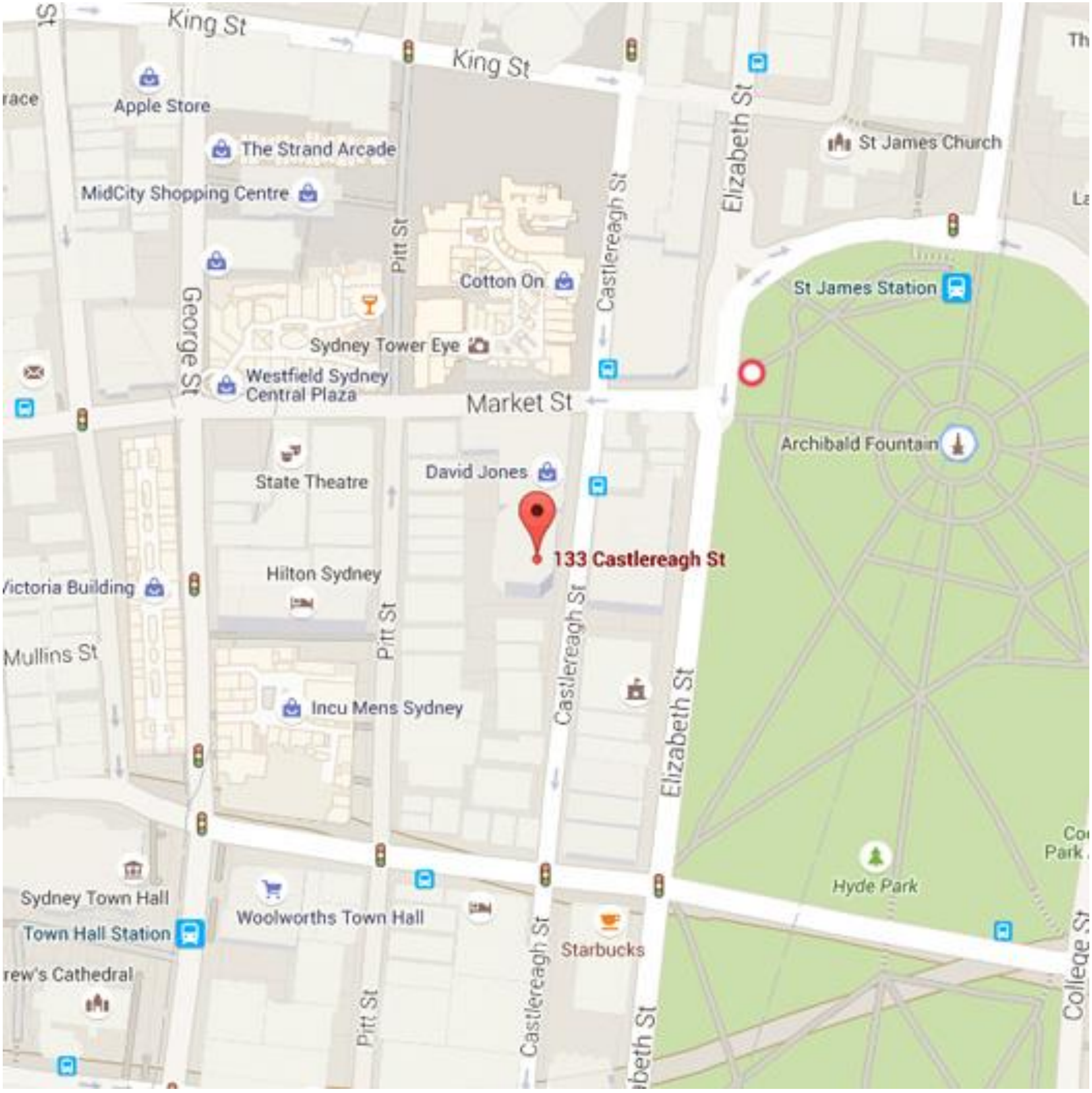
Parsons Brinckerhoff (2013) *Jose D. Leon Guerrero Commercial Port of Guam Master Plan Update 2013 Report*. Tamuning, Guam.

Ports of Auckland (POAL) (2015) Data acquired from interview survey.

R Shibasaki and T Kawasaki (2016) Modelling international maritime container cargo flow and policy simulation in South Asia: An application of network equilibrium assignment model on a global scale. *World conference on transport research – WCTR 2016 Shanghai.* 10-15 July 2016.

11 Location Map

LOGMS 2016 – Location Map



Address

Stockland Building
Level 17
133 Castlereagh St
Sydney 2000

Getting There

By train

The nearest station is St James Station with an approximate walking distance of 350 metres.

- Catch a train to St James Station.
- Alight from the train at St James Station and follow the signs towards Elizabeth St exit.
- Upon St James Station Elizabeth St exit, cross the set of lights to approach Market St and continue along Market St
- First intersection will be Castlereagh St, Turn left and continue walking for 100m and CBD Campus is on the right side of the street

By bus

The nearest bus stops are located on Castlereagh Street or on Elizabeth Street as identified on the map by the bus stop icons.