

RGC Ref. No.: UGC/FDS14/E07/18 _____ (please insert ref. above)
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**RESEARCH GRANTS COUNCIL
COMPETITIVE RESEARCH FUNDING SCHEMES FOR
THE LOCAL SELF-FINANCING DEGREE SECTOR**

FACULTY DEVELOPMENT SCHEME (FDS)

Completion Report
(for completed projects only)

<p><u>Submission Deadlines:</u></p> <ol style="list-style-type: none"> 1. Auditor's report with unspent balance, if any: within six months of the approved project completion date. 2. Completion report: within 12 months of the approved project completion date.
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Part A: The Project and Investigator(s)

1. Project Title

Three-echelon collaborative slot allocation planning for liner shipping revenue
management under uncertain demand

2. Investigator(s) and Academic Department(s) / Unit(s) Involved

Research Team	Name / Post	Unit / Department / Institution
Principal Investigator	Dr. WONG Yin Cheung, Eugene / Associate Professor	Department of Supply Chain and Information Management, School of Decision Sciences, The Hang Seng University of Hong Kong
Co-Investigator(s)	Dr. MO Yiu Wing, Daniel / Associate Professor	Department of Supply Chain and Information Management, School of Decision Sciences, The Hang Seng University of Hong Kong
	Dr. LAM Siu Lee, Jasmine / Associate Professor	School of Civil and Environmental Engineering, Nanyang Technological University
	Dr. YIP Tsz Leung / Associate Professor	Department of Logistics and Maritime Studies, The Hong Kong Polytechnic University
	Prof. SONG Dong-Wook / Professor	World Maritime University
	Ms. CHEUNG Charing / General Manager, Network Control Centre	Orient Overseas Container Line Ltd.
	Ms. WONG Bess / Manager –Trade Traffic	Orient Overseas Container Line Ltd.

	Section Head	
Others	Dr. Kev Ling / Senior Research Assistant	Department of Supply Chain and Information Management, School of Decision Sciences, The Hang Seng University of Hong Kong

3. Project Duration

	Original	Revised	Date of RGC / Institution Approval (<i>must be quoted</i>)
Project Start Date	1 January 2019	N/A	
Project Completion Date	31 December 2020	30 June 2021	30 July 2020
Duration (<i>in month</i>)	24 months	30 months	30 July 2020
Deadline for Submission of Completion Report	31 December 2021	30 June 2022	30 July 2020

Part B: The Final Report

5. Project Objectives

5.1 Objectives as per original application

1. To review the current operations of ship liner slot allocation on multiple trade lanes and service loops in a ship alliance and identify critical factors that affect decisions regarding daily slot allocation planning
2. To develop a novel method as a decision support tool to enhance the current slot allocation and exchange operations with better utilisation and yield on the local, regional and global levels;
3. To establish best-practice methods for the shipping industry to achieve better usage and yield in complex slot allocation in multiple trade lanes, service loops, port-pairs and ship alliance;
4. To enhance the knowledge of students and industry practitioners regarding the importance of using decision support tools to assist in the optimisation of slot planning and allocation with respect to utilisation and yield in multiple trade lanes and service loops, instead of obtaining feasible solutions with conventional calculation tools; and
5. To enhance the existing education materials on maritime slot planning and allocation from the seminar, workshop, developed decision support tools and pilot implementation on slot allocation optimisation.

5.2 Revised objectives

Date of approval from the RGC: N/A

Reasons for the change: N/A

1. N/A

2. N/A

3. N/A

5.3 Realisation of the objectives

(Maximum 1 page; please state how and to what extent the project objectives have been achieved; give reasons for under-achievements and outline attempts to overcome problems, if any)

1. *Objective 1: To review current operations of ship liner slot allocation and identify critical factors involved.*
 - (1) Upon carrying out operations reviews, alliance trend evaluation, and literature review, critical factors affect the slot allocation planning are identified. Meetings have been carried out with local and overseas Co-Investigators in discussing the research content and methodology.
 - (2) Meetings with ship liners (RCL, OOCL and MSC), slot allocation operations process and data are collected for analysis. Further meetings with Emirates Shipping Line have also been carried out.
 - (3) A workshop on maritime operations has been held on 8 April 2020, with Ms Queenie Liu, Senior Manager, Container Control, Emirates Shipping Line to share the operations details with project team and students.

2. *Objective 2: To develop a novel method as a decision support tool to enhance current slot allocation*

- (1) With literature review, company operations review, data collection, and statistical analysis carried out, critical factors affect the slot allocation planning are identified. Slot allocation optimisation simulation tools are developed using GA and DNN, considering with various scenarios.
- (2) A conference paper “Modelling multi-echelon collaborative slot allocation planning for liner shipping revenue management” has been presented in the 27th Annual Conference of the IAME in Greece.
- (3) A journal paper, “Three-echelon Slot Allocation for Yield and Utilisation Management in Ship Liner Operations” has been compiled and submitted to a journal CAOR (Second revision submitted).
- (4) A journal paper, “Yield and port performance shipping allocation model for revamp service deployments under a dynamic trading landscape”, is published in TRC.
- (5) A journal paper, “Modelling the non-cooperative slot exchange of ship liners to ensure profitability and stability in shipping alliances in the COVID-19 pandemic” has been submitted to TRE.

3. *Objective 3: To establish best-practice methods for the shipping industry to achieve better usage and yield*

- (1) Several identified ship liner companies are collaborated in the project, with meetings being carried out. Decision support models on slot allocation and exchange have been developed to assist trade traffic planner in utilizing vessel spaces during the slot allocation operations.
- (2) Cases on slot allocation, new service deployment, and slot exchange have been compiled in a booklet as sharing of best practice methods (Annex XI).
- (3) A conference paper “Modelling n-person non-cooperative equilibria in slot exchange of ship liners under a ship alliance” has been presented in IFSPA in Hong Kong.
- (4) The complex vessel slot allocation operations have been analysed, including the potential further development area on slot exchange, involving bargaining theory and game theory. The concept and ideas have been presented in the international conference. A further model has been developed.
- (5) The non-cooperative game mechanism research context has been presented, titled “Stabilizing slot exchange of ship alliance members via bargaining theory and non-cooperative game mechanism”, in 9th International Conference of Logistics and Maritime Systems, 14-16 August 2019, Singapore.

4. *Objective 4: To enhance the knowledge of students and industry practitioners*

- (1) 3 FYP and 1 SYP student teams are formed. With the guidance and advice from PI, Co-I, Industry advisors and RA, they participated in the operations review, data collection, and optimization simulations on vessel allocation and slot exchange. Through the project implementation, they increased the awareness of ship liners operations, acquired knowledge and skills in data analytics and simulations.
- (2) A Special Issue of journal TRE with the theme of “Decision Analytics and Trade Ideology: New Perspectives of Maritime Logistics” has been carried out. Dr. Jasmine Lam, Dr. T.L. Yip and Dr. Eugene Wong, are the guest editors of SI. There are 22 paper submissions, with 7 papers accepted, after extensive reviews.
- (3) A booklet, titled “Sustainable Transport and Logistics – Three-echelon collaborative slot allocation planning for liner shipping revenue management under uncertain demand” (Annex XI), is produced for students and practitioners.
- (4) A conference presentation “Optimising maritime vessel slot allocation planning with Genetic Algorithm: The case for a Trans-Pacific Trade service” has been carried out in International Conference on IEEM at Macau.

5. *Objective 5: To enhance the existing education materials on maritime slot planning and allocation from the seminar, workshop, developed decision support tools on slot allocation optimisation.*

- (1) A seminar has been conducted (Speakers: Ir. Dr. Patrick Lee, Advisor Nippon Express and Mr. Tony Tse, Senior Manager, Terminal Development, Hutchison Ports) on 28 March 2019 to understand the latest issues on cargo trends, hub selection, terminal operations.
- (2) A seminar, “Emerging trend on trade and technological development in maritime and logistics” has been carried out on 7 November 2019, with two speakers invited (Mr. Lam Wing Chiu, Head of Terminal Development, Infrastructure Development, Modern Terminals and Mr. Philip Cheng, General Manager, Trade and Sales (HK, South China and Taiwan), MSC (HK)).
- (3) A workshop on Maritime Operations has been held on 8 April 2020 with Ms Queenie Liu, Emirates Shipping Line being invited to share and discuss about the topic with the project team and the students.
- (4) A seminar has been conducted (Speaker: Dr. Erik Hemmer, Director Corporate Strategy and Fleet, Lufthansa Cargo AG, Frankfurt, Germany) on 5 November 2020 to discuss about the volatility of cargo logistics under pandemic outbreak, cyber disruption and trading uncertainty.

5.4 Summary of objectives addressed to date

Objectives <i>(as per 5.1/5.2 above)</i>	Addressed <i>(please tick)</i>	Percentage Achieved <i>(please estimate)</i>
1. To review the current operations of ship liner slot allocation on multiple trade lanes and service loops in a ship alliance and identify critical factors that affect decisions regarding daily slot allocation planning;	✓	100%
2. To develop a novel method as a decision support tool to enhance the current slot allocation and exchange operations with better utilisation and yield on the local, regional and global levels;	✓	100%
3. To establish best-practice methods for the shipping industry to achieve better usage and yield in complex slot allocation in multiple trade lanes, service loops, port-pairs and ship alliance;	✓	100%
4. To enhance the knowledge of students and industry practitioners regarding the importance of using decision support tools to assist in the optimisation of slot planning and allocation with respect to utilisation and yield in multiple trade lanes and service loops, instead of obtaining feasible solutions with conventional calculation tools; and	✓	100%
5. To enhance the existing education materials on maritime slot planning and allocation from the seminar, workshop, developed decision support tools and pilot implementation on slot allocation optimisation.	✓	100%

6. Research Outcome

6.1 Major findings and research outcome

(Maximum 1 page; please make reference to Part C where necessary)

Major findings and research outcome include:

- *Multi-echelon collaborative slot allocation planning model for ship liner operations* – novel slot allocation models have been developed for multi-echelon collaborative slot allocation planning in local, regional and global perspectives. Optimisation methods were developed based on branch-and-bound search, genetic algorithm and deep neural network theories. Simulation results and model sensitivity of the developed algorithms were evaluated, with various scenarios, including single-, two- and multiple-service routes with cargo shifting cases.
- *Yield and Port Performance Shipping Allocation Model for new service deployments* – a trade- and port-performance model for predicting shipping network yields were developed for revamp service deployment analysis, with optimized sets of allocated spaces on selected port calls at the service and shipment levels.
- *Non-Cooperative Slot Exchange Model for ship liners in shipping alliances* – The competitive slot exchange behaviours of the ship liners in an alliance are modelled, considering iterative bidding for slot orders through non-cooperative adjustments to the basic slot entitlements of liners. Evolutionary game theory is combined with the genetic algorithm to optimise the payoff for the alliance and individual liners.
- *Journal paper on slot allocation planning* – a journal paper, “Three-echelon Slot Allocation for Yield and Utilisation Management in Ship Liner Operations” has been compiled and submitted to a journal Computers and Operations Research. A second revision has been submitted.
- *Journal paper on revamp service deployments* – A journal paper, “Yield and Port Performance Shipping Allocation Model for Revamp Service Deployments under a Dynamic Trading Landscape” is published in Transportation Research Part C: Emerging Technologies.
- *Journal paper on non-cooperative slot exchange* – A journal paper, “Modelling the Non-Cooperative Slot Exchange of Ship Liners to Ensure Profitability and Stability in Shipping Alliances in the COVID-19 Pandemic” has been compiled and submitted to Transportation Research Part E: Logistics and Transportation Review.
- *Journal Special Issue* – A Special Issue of Transportation Research Part E: Logistics and Transportation Review with the theme of “Decision Analytics and Trade Ideology: New Perspectives of Maritime Logistics” has been carried out. Three project team members, Dr. Jasmine Lam, Dr. T.L. Yip and Dr. Eugene Wong, are the guest editor of the special issue. There are 22 paper submissions, with 7 journal papers accepted, after extensive reviews.
- *Booklet publication* – a booklet, titled “Sustainable Transport and Logistics – Three-echelon collaborative slot allocation planning for liner shipping revenue management under uncertain demand” (Annex XI), is compiled and printed for students and practitioners
- *Conference presentations* – Six conference presentations have been conducted in disseminating project deliverables and exchanging ideas on slot allocation and exchange on ship liner operations.
- *Final year Projects and Senior Year Project* – 3 Final Year Project teams and 1 Senior Year Project team participated in the operations review, data collection, and optimization simulations on vessel allocation and slot exchange.
- *Seminar and workshops* – Three seminars and one workshop are successfully organized, Students, academics and practitioners gained the knowledge of the principle and operations on the vessel slot allocation planning and operations.
- *Newsletter and website* – Seminars and workshops as well as details of the project are shared on the website and newsletter.

6.2 Potential for further development of the research and the proposed course of action (Maximum half a page)

Potential for further development of research include:

- Modelling non-cooperative slot exchange of multiple ship liners in ensuring profitability and stability in a shipping alliance.
- Simulating long-haul services with space utilisation through short-haul shipments on the open spaces of a vessel in a service route.
- Investigating the waves of COVID-19 impacts towards the ship liner operations as well as container fleetsize planning and availability in the market.

7. Layman's Summary

(Describe in layman's language the nature, significance and value of the research project, in no more than 200 words)

In the highly competitive maritime transportation business, ship liners continuously encounter mismatches between supply and demand and intense rivals' price-cutting actions. Most liners actively improve utilisation of mega-vessels and form alliances to lower their operation costs and enhance their service networks. International liners run long-haul services with vessel slots to be used with shipments from multiple trade lanes, with the slot planning considering multiple loading and discharging ports, shipment yields and empty repositioning. Current slot planning operations in liners only provide feasible solutions without optimising the yield of each service trade lane. Previous academic studies mainly focus on vessel slot allocation of single service loop and thus unable to reflect and solve the real situation. Some of them consider twenty-foot equivalent unit constraints, but not individual size type and weight constraints. This project develops a novel three-echelon collaborative slot allocation planning model operating with the dynamics among local, regional hub and global scales on container loading and discharge at various vessels in multiple ports. A two-stage optimisation is developed to improve usage and yield with consideration of short-haul shipments utilising long-haul services, slot exchange amongst ship liners in an alliance and cargo shifting amongst multiple trade lanes and service loops. The model assists trade traffic planners in collaborating with regions and maximising slot usage and yield. The model ensures cargo dimensions and weight fall within the cargo payload capacity and verified gross mass requirements, preventing vessels from sailing with excessive weight and leading to vessel damage, excessive fuel usage and the emission of unnecessary environmentally unfriendly greenhouse gases.

Part C: Research Output**8. Peer-Reviewed Journal Publication(s) Arising Directly From This Research Project**

(Please attach a copy of the publication and/or the letter of acceptance if not yet submitted in the previous progress report(s). All listed publications must acknowledge RGC's funding support by quoting the specific grant reference.)

The Latest Status of Publications				Author(s) (denote the corresponding author with an asterisk*)	Title and Journal / Book (with the volume, pages and other necessary publishing details specified)	Submitted to RGC (indicate the year ending of the relevant progress report)	Attached to this Report (Yes or No)	Acknowledged the Support of RGC (Yes or No)	Accessible from the Institutional Repository (Yes or No)
Year of Publication	Year of Acceptance (For paper accepted but not yet published)	Under Review	Under Preparation (optional)						
2021				Wong, E.Y.C.*, Ling, K.K.T.*, Zhang, X.	Yield and Port Performance Shipping Allocation Model for Revamp Service Deployments under a Dynamic Trading Landscape / Transportation Research Part C: Emerging Technologies / Volume 130, 103279. https://doi.org/10.1016/j.trc.2021.103279		Yes (Annex I)	Yes	Yes (https://researchdb.hsu.edu.hk/view/publication/202100119)
		2022 (2 nd revision submitted)		Wong, E.Y.C., Ling, K.K.T., Tai, A.H.L., Lam, J.S.L., and Zhang, X.	Three-echelon Slot Allocation for Yield and Utilisation Management in Ship Liner Operations / Computers & Operations Research		Yes (Annex II)	Yes	No
		2022 (Submitted)		Wong, E.Y.C., Ling, K.K.T., Tai, A.H.L. and Mo, D.Y.W.	Modelling the Non-Cooperative Slot Exchange of Ship Liners to Ensure Profitability and Stability in Shipping Alliances in the COVID-19 Pandemic / Transportation Research Part E: Logistics and Transportation Review		Yes (Annex III)	Yes	No

9. Recognized International Conference(s) In Which Paper(s) Related To This Research Project Was / Were Delivered

(Please attach a copy of each conference abstract)

Month / Year / Place	Title	Conference Name	Submitted to RGC (indicate the year ending of the relevant progress report)	Attached to this Report (Yes or No)	Acknowledged the Support of RGC (Yes or No)	Accessible from the Institutional Repository (Yes or No)
May / 2019 / Hong Kong	Modelling n-person non-cooperative equilibria in slot exchange of ship liners under a ship alliance	International Forum on Shipping, Ports and Airports (IFSPA), 20-24 May 2019, Hong Kong.	2019	No	Yes	Yes (https://researchdb.hsu.edu.hk/view/publication/201900378)
June / 2019 / Greece	Modelling multi-echelon collaborative slot allocation planning for liner shipping revenue management	27th Annual Conference of the International Association of Maritime Economists (IAME), 25-28 June 2019, Athens, Greece.	2019	No	Yes	Yes (https://researchdb.hsu.edu.hk/view/publication/201900373)
August / 2019 / Singapore	Stabilizing slot exchange of ship alliance members via bargaining theory and non-cooperative game mechanism.	9th International Conference of Logistics and Maritime Systems, 14-16 August 2019, Singapore.	2019	No	Yes	Yes (https://researchdb.hsu.edu.hk/view/publication/201900374)
December / 2019 / Macau	Optimising maritime vessel slot allocation planning with Genetic Algorithm: The case for a Trans-Pacific Trade service	International Conference on Industrial Engineering & Engineering Management, 15-18 Dec 2019, Macau	2019	No	Yes	Yes (https://researchdb.hsu.edu.hk/view/publication/201900375)
June / 2020 / Hong Kong	Decision analytics system on new service deployments for supply chain pattern changes under US-China trade protectionism impact	28th Annual Conference of the International Association of Maritime Economists (IAME) 2020, Hong Kong		Yes (Annex IV)	Yes	Yes (https://researchdb.hsu.edu.hk/view/publication/202000257)
September / 2021 / Japan	Development of Container Fleet Size Model for Ship Liner Equipment and Allocation Operations Planning	8 th International Conference on Frontiers of Industrial Engineering (ICFIE 2021), 11-13 June 2021, Singapore		Yes (Annex V)	Yes	Yes (https://researchdb.hsu.edu.hk/view/publication/202100237)

12. Other Impact

(e.g. award of patents or prizes, collaboration with other research institutions, technology transfer, teaching enhancement, etc.)

- Collaborated with other research institutions: The development of the slot allocation planning, and exchange has been collaborated with Nanyang Technological University (NTU) of Singapore and the City University of Hong Kong.
- Collaborated with ship liners: The slot allocation planning optimization and case studies have been collaborated with OOCL, MSC, and Emirates Shipping Line.
- Collaborated in journal special issue: The special issue of Transportation Research Part E: Logistics and Transportation Review has been collaborated with Nanyang Technological University (NTU) of Singapore, the Hong Kong Polytechnic University, Hong Kong and University of Manitoba, Canada. (Annex X)
- Materials in the academic modules, including Shipping and Transport Logistics, and Transport Logistics and Law, have been enhanced in the area of maritime transportation.

13. Statistics on Research Outputs

	Peer-reviewed Journal Publications	Conference Papers	Scholarly Books, Monographs and Chapters	Patents Awarded	Other Research Outputs (please specify)	
					Type	No.
No. of outputs arising directly from this research project	1 (published) and 2 (under review)	6	N/A	N/A	Journal Special Issue	1
					Booklet	1

14. Public Access Of Completion Report

(Please specify the information, if any, that cannot be provided for public access and give the reasons.)

Information that Cannot Be Provided for Public Access	Reasons
N/A	N/A