**Institution: Plymouth University**

**Unit of Assessment:** 19 Business and Management

**Title of case study:** Integrated Container Fleet Management in Transportation Service Systems.

**1. Summary of the impact** (indicative maximum 100 words)

The research outlined in this case study has led to (1) an understanding of the complexities of shipping containerisation in the real world, embracing container fleet sizing, container leasing, repositioning of empty containers, ship scheduling, and shipping emissions; (2) innovative concepts and approaches such as inventory-based threshold policies and integrated container management; (3) development of a formal model and associated decision-support tools for use in the management of containers by key industry players – shipping companies and port authorities – in collaboration with local academic partners. The research has been translated into impact on shipping lines and container ports in several countries.

**2. Underpinning research** (indicative maximum 500 words)

Containerisation is at the heart of the global logistics industry responsible for the transport of goods around the world. Container shipping itself is one of the fastest growing shipping industry sectors – the annual growth rate in 1988-2008 was around 10% in container ship fleets, container fleets, and container port throughput. Efficiency in the logistics of the container supply-chain itself has become critical given spiralling fuel costs, the scale of emissions from shipping, and, in particular, the problem of empty containers. Over 90% of the UK imports and exports are moved by containers, with at least one in every two incoming containers leaving the UK empty. The cost of moving empty containers around the globe exceeded US$16 billion in 2002. The problem here is managing supply-chain logistics in the context of the realities of dynamic operations, multiple uncertainties, global networks, severe imbalance in the flow of goods between East & West, and the impact of recession.

This has been the focus of research at Plymouth led by Professor Dong-Ping Song who has been working on modelling and optimisation of manufacturing and service logistics systems for two decades. From 2001 to 2004 he was a key member of the EPSRC/DfT funded research project “Container World” at Imperial College, modelling the world container shipping business. This was substantially developed in 2005-2012 with members of the Plymouth University International Shipping & Logistics Group.

Song has conducted a series of pioneering studies of container shipping. He was among the first to propose new concepts, e.g. inventory-based threshold control policies for empty container management, in which the movement of empty containers is determined by the target inventory levels at ports and on vessels (cf. Song, 2005, Optimal threshold control of empty vehicle redistribution in two depot service systems, *IEEE Trans. On Automatic Control*). Concepts were further developed to facilitate easy-to-operate and near-to-optimal policies for repositioning empty containers in dynamic stochastic situations. He also developed a decision-support system for integrated container fleet management so that decisions in different areas (e.g. in relation to fleet-sizing, leasing-in, leasing-off, distributing, and repositioning) could be better coordinated.

Song’s work combined analytical and simulation methods to establish and evaluate the optimality of container management policies for complex shipping systems. This has also resulted in a novel way of estimating CO2 emissions from container shipping which includes operational data – exclusion of which led to flawed calculation of emissions. Song developed new methods for, and provided insights to, robust container-ship scheduling which minimized shipping emissions. The research has appeared in 14 refereed journal articles, one book, one book chapter, 10 conference articles, and 6 seminars to industries and international academics in the period 2008-2012. Implementation in key installations, driven by the need for efficiency,

has informed and changed industry practice. Indeed a recently published book by Song (2013) entitled *Optimal Control and Optimization of Stochastic Supply Chain Systems* (Advances in Industrial Control) provides a ground breaking analysis and assessment of containerisation that has been applauded by the industry as a relevant and practical guide.

**3. References to the research** (indicative maximum of six references)

Note: the underlined authors are Plymouth University staff. Dong was a Post-Doctoral researcher at Plymouth at the time of the underlying research. (With 2011 Journal Citation Report Impact Factor (IF) and 2010 ABS ranking).


1. Song, D.P. and Dong, J.X. (2012), Cargo routing and empty container repositioning in multiple shipping service routes, *Transportation Research Part B: Methodological*, 46(10): 1556-1575. (DOI: 10.1016/j.trb.2012.08.003) [IF = 2.856, ABS = 4*].

2. Qi, X.T. and Song, D.P. (2012), Minimising fuel emissions by optimising vessel schedules in liner shipping with uncertain port times, *Transportation Research Part E: Logistics and Transportation Review*, 48(4): 863-880. (DOI: 10.1016/j.tre.2012.02.001) [IF = 1.648; ABS = 3*]

3. Dong, J.X. and Song, D.P. (2012), Quantifying the impact of inland transport time on container fleet sizing in a liner shipping service with uncertainties, *OR Spectrum*, 34(1):155-180 (DOI: 10.1007/s00291-009-0185-4). [IF = 1.233; ABS = 3*]

4. Dong, J.X. and Song, D.P. (2009), Container fleet sizing and empty repositioning in liner shipping systems, *Transportation Research Part E: Logistics and Transportation Review*, 45(6): 860-877(DOI:10.1016/j.tre.2009.05.001). [IF = 1.648; ABS = 3*]

5. Song, D.P. and Earl, C.F. (2008), Optimal empty vehicle repositioning and fleet-sizing for two-depot services systems, *European Journal of Operational Research*, 185, 760-777. (DOI:10.1016/j.ejor.2006.12.034). [IF = 1.815; ABS = 3*]

6. Song, D.P. and Carter, J. (2008), Optimal empty vehicle redistribution for hub-and-spoke transportation systems, *Naval Research Logistics*, 55(2): 156-171. (DOI: 10.1002/nav.20274) [IF = 1.308; ABS = 3*]


**4. Details of the impact** (indicative maximum 750 words)

This section covers the impact of the research (1) on non-academic communities through exploitation, by joint working with others, and (2) by other institutes who have taken up the work (from publication or other dissemination) and applied it without further direct Plymouth involvement.

Song was the international collaborator of the research grant awarded to Prof. Qiushuang Chen at Nankai University in China ("*Coordination Mechanism and Cooperative Optimization and Scheduling in Green Container Shipping Supply Chains*", funded by National Science Foundation of China). Song's research work on container fleet management and liner shipping scheduling in the context of multiple uncertainties and ship emissions has been further developed in the above project, and exploited through application to the operations of industrial partners including Tianjin Port, and the EAS International Shipping Cooperation. This has helped industrial partners (1) improve their container inventory management through better coordination and (2) improve their operational activities by optimising and balancing multiple

objectives (economic and environmental performance) (cf. Source 1).

Song was invited as a visiting researcher at the Hong Kong University of Science & Technology in April 2011 and led a research seminar: "*CO2 emission from container shipping services*". An outcome of the collaboration between Professor Song and Professor Xiangtong Qi involved the design of robust containership scheduling with uncertainty and emission minimization. This has been explicitly exploited as a significant part of the project, "*Transforming Hong Kong's Ocean Container Transport Logistics Network*" (funded by the Research Grants Council of Hong Kong), which emphasized local practical impact by providing prototypes for the industry and managerial guidance for policy makers (cf. Source 2).

Pusan National University independently took up Song's research on container fleet management and empty container repositioning. This was the basis of their work that was exploited by the Korean liner shipping company, Hyundai Merchant Marine, and the software company, Softship Data AG, Germany. The research has benefited both companies by providing them with the tools for understanding and modelling resource utilization (cf. Source 3).

Singapore National University took up Song's work on container shipping, as the basis for collaboration with industrial partners. For example, the project "*Liner Shipping Network Design: Model Development, Algorithm Design and Applications*", used some of Song's results (e.g. containership routing and scheduling, and empty container repositioning) to change practice in the major Singapore-based shipping line, APL Co Pte Ltd. (a unit of the multi-national Neptune Orient Lines, the 7th largest container shipping company in the world). (cf. Source 4).

**5. Sources to corroborate the impact** (indicative maximum of 10 references)

Because of the English-language difficulties of the Chinese business users involved, we have obtained supporting statements from those English-speaking academic collaborators who had the closest liaison with the business users.

1. Statement from Nankai University, China, on collaboration and exploitation of research with Tianjin Port and the EAS International Shipping Cooperation.

2. Statement from Hong Kong University of Science and Technology, Hong Kong, on collaboration and exploitation of research for the Hong Kong Ocean Container Transport Logistics Network.

3. Statement from Pusan National University, South Korea, on exploitation of research with Hyundai Merchant Marine, Korea, and Softship Data, Germany.

4. Statement from Singapore National University, Singapore, on exploitation of research with APL Co Pte Ltd.

5. Research Councils UK (Gateway to Research) (2008) Establishing New Collaborations with Academic and Industrial Communities http://gtr.rcuk.ac.uk/project/FFBA40B4-F164-4320-A9AC-4D33DC642C8D