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A novel memetic algorithm with a
deterministic parameter control
for efficient berth scheduling at
marine container terminals

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Abstract

Purpose – The volumes of international containerized trade substantially increased over the past years. In the meantime, marine container terminal (MCT) operators are facing congestion issues at their terminals because of the increasing number of large-size vessels, the lack of innovative technologies and advanced handling equipment and the inability of proper scheduling of the available resources. This study aims to propose a novel memetic algorithm with a deterministic parameter control to facilitate the berth scheduling at MCTs and minimize the total vessel service cost.

Design/methodology/approach – A local search heuristic, which is based on the first-come-first-served policy, is applied at the chromosomes and population initialization stage within the developed memetic algorithm (MA). The deterministic parameter control strategy is implemented for a custom mutation operator, which alters the mutation rate values based on the piecewise function throughout the evolution of the algorithm. Performance of the proposed MA is compared with that of the alternative solution algorithms widely used in the berth scheduling literature, including a MA that does not apply the deterministic parameter control strategy, typical evolutionary algorithm, simulated annealing and variable neighborhood search.

Findings – Results demonstrate that the developed MA with a deterministic parameter control can obtain superior berth schedules in terms of the total vessel service cost within a reasonable computational time. Furthermore, greater cost savings are observed for the cases with high demand and low berthing capacity at the terminal. A comprehensive analysis of the convergence patterns indicates that introduction of the custom mutation operator with a deterministic control for the mutation rate value would provide more efficient exploration and exploitation of the search space.

Research limitations/implications – This study does not account for uncertainty in vessel arrivals. Furthermore, potential changes in the vessel handling times owing to terminal disruptions are not captured.

Practical implications – The developed solution algorithm can serve as an efficient planning tool for MCT operators and assist with efficient berth scheduling for both discrete and continuous berthing layout cases.

Originality/value – The majority of studies on berth scheduling rely on the stochastic search algorithms without considering the specific problem properties and applying the guided search heuristics. Unlike canonical evolutionary algorithms, the developed algorithm uses a local search heuristic for the chromosomes and population initialization and adjusts the mutation rate values based on a deterministic parameter control strategy for more efficient exploration and exploitation of the search space.

Keywords Marine container terminals, Berth scheduling, Deterministic parameter control, Memetic algorithms, Vessel service cost savings

Paper type Research paper

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1. Introduction
According to the recent statistical data, provided by the United Nations Conference on Trade and Development (UNCTAD), volumes of the international maritime trade have been rapidly growing since 2009 (UNCTAD, 2015). A total of 9.8 billion tons of cargo were carried by vessels in 2014, which is 20.2 per cent more as compared to the total volume of cargo transported in 2009. In five years, the container volumes increased by 30.9 per cent and the dry cargo volumes increased by 11.8 per cent, while major bulk and liquid bulk cargoes increased by 33.0 and 6.5 per cent, respectively (UNCTAD, 2015). Such a significant increase in the international containerized trade volumes requires marine container terminal (MCT) operators to improve the terminal productivity and efficiently serve the growing demand (Bentolila et al., 2016; Rahman et al., 2016; Lu et al., 2016).

However, the opposite tendencies have been recently observed at major MCTs. The largest European ports (i.e. Rotterdam, Hamburg, Antwerp) reported the inability of the port infrastructure to efficiently serve the increasing amount of megaships (Port Finance, 2014). Long congestion periods were observed at the Port of Los Angeles (USA) owing to labor strikes, which resulted in a decrease in the West Coast-laden traffic by 12 per cent in the first three months of 2015 (Journal of Commerce, 2015). The expected vessel waiting time of up to three days was reported in May 2016 at certain ports of Malaysia: Kuantan, Penang, Pasir Gudang, etc. (Ben Line Agencies, 2016). The American Shipper (2015) and World Shipping Council (2015) outline the following key factors causing the port congestion:

- liner shipping alliances;
- increasing size of vessels;
- lack of innovative technologies; and
- chassis availability.

The MCT operators have to develop new strategies and innovative approaches to enhance efficiency of their operations and alleviate negative externalities from the congestion issues (World Shipping Council, 2015). This paper focuses on the berth scheduling problem (BSP), which deals with the assignment of vessels to the available berths at the given MCT, and defining the sequence of vessels served at each berth. An efficient berth schedule is crucial for the MCT operations, as it directly affects the vessel turnaround time. The latter is considered as an important MCT performance indicator (Bierwirth and Meisel, 2015). A novel memetic algorithm (MA), which uses a local search heuristic for the chromosomes and population initialization and adjusts the mutation rate values based on a deterministic parameter control strategy, is proposed to assist the MCT operators with construction of efficient berth schedules. The rest of the paper is organized as follows. Section 2 presents a review of the BSP literature with focus on the developed solution algorithms, while Section 3 describes the problem studied in this paper. Section 4 presents a mixed-integer nonlinear mathematical model for the problem, while Section 5 provides a detailed description of the proposed solution algorithm. Section 6 discusses the computational experiments, conducted in this study, to evaluate the efficiency of the developed algorithm, while Section 7 summarizes the findings and outlines the future research extensions.

2. Literature review
The BSP can be reduced to the unrelated machine scheduling problem, where the arriving jobs should be assigned for processing on the available machines, which have different properties. The latter operations research problem is known to have $NP$-hard complexity (Pinedo, 2008; Bierwirth and Meisel, 2015). The $NP$-hard problems are unlikely to be solved...
using the exact optimization algorithms in an acceptable computational time for the realistic-size problem instances. Many of the published to-date BSP studies applied the stochastic search algorithms (e.g. evolutionary algorithms – EAs, simulated annealing – SA, Tabu search – TS, particle swarm optimization – PSO, etc.), which do not guarantee the global optimality of the berth schedules, but they are able to obtain the “good-quality” berth schedules within a reasonable computational time. The literature review presented herein mainly focuses on the solution algorithms that were designed to solve the BSP. For a more detailed description of the BSP papers, this study refers to Bierwirth and Meisel (2010, 2015) and Carlo et al. (2013). An overview of the collected BSP papers is presented next.

Nishmura et al. (2001) proposed a nonlinear mathematical formulation for the dynamic BSP in the public berth system. The objective aimed to minimize the total vessel service time. An EA-based heuristic was developed to solve the problem. Computational experiments demonstrated that the presented solution approach provided solutions, close to the ones that were obtained by the Lagrangian relaxation-based algorithm for the large-size problem instances. Kim and Moon (2003) and Dai et al. (2008) developed SA-based algorithms to solve BSPs, aiming to minimize the total vessel service cost. Cordeau et al. (2005) presented a BSP formulation, minimizing the total weighted vessel service time. A TS algorithm was designed to solve the problem. Zhou et al. (2006) developed an EA for the BSP with variable vessel service priorities, minimizing the total waiting time of vessels. Imai et al. (2007a) formulated the BSP at the MCT with indented berths for faster service of megaships, minimizing the total vessel service time. An EA was developed to solve the problem. Wang and Lim (2007) presented a stochastic beam search (SBS) heuristic to solve the BSP. The objective minimized the total vessel service cost, associated with possible unallocation, and penalties owing to deviations from the desired berthing positions and late vessel departures. Hansen et al. (2008) and Lee and Chen (2009) used a variable neighborhood search (VNS) heuristic to solve BSPs, minimizing the total vessel service cost and maximizing the berth utility index, respectively.

Imai et al. (2008) formulated the BSP at the MCT, where vessels with excessive waiting times were diverted for service at an external terminal. The objective aimed to minimize the total vessel service time at the external terminal. The problem was solved using an EA. Golias et al. (2010a) developed an EA to solve BSP, aiming to minimize the total vessel service time, delayed departures, fuel consumption and emissions produced. Golias et al. (2010b) presented a lambda-optimal heuristic to solve the BSP, minimizing the total weighted service time of vessels. Lee et al. (2010) developed two versions of a greedy randomized adaptive search procedure to solve the BSP, aiming to minimize the total weighted turnaround time of vessels. Lalla-Ruiz et al. (2012) formulated the BSP, directed to minimize the total service time of vessels. The authors presented a heuristic based on TS and path re-linking. Imai et al. (2013) evaluated various MCT layouts, including conventional, channel and indented layouts. The objective aimed to minimize the total vessel service time, and an EA was applied to solve the problem.

Ting et al. (2014) proposed a PSO algorithm for the BSP, minimizing the total turnaround time of vessels. Frojan et al. (2015) formulated a BSP at the MCT with multiple quays, minimizing the total vessel service cost. An EA with a local search heuristic was developed to solve the problem. Hu (2015a) studied a BSP, taking into consideration a periodic balancing utilization of quay cranes and aiming to minimize the total vessel service cost. A set of heuristics was developed to solve the problem. Emde and Boysen (2016) focused on the BSP, minimizing the total waiting time of vessels and the number of delayed containers. The authors presented an SA-based heuristic to solve the problem. Mauri et al. (2016) proposed an adaptive large neighborhood search heuristic for the BSP. The objective minimized the
total vessel service time. The heuristic changed the solutions using an adaptive probabilistic mechanism for destroy and repair operators. Dulebenets (2017a) proposed an adaptive EA for the BSP, where the mutation rate was altered based on feedback from the search. The objective of the proposed model aimed to minimize the total weighted vessel service cost. Dulebenets et al. (2017) developed a set of Hybrid EAs for the green BSP, where the carbon dioxide emission cost because of container handling was included in the objective function of the model.

Several papers captured uncertainty in vessel arrival and handling times. Xu et al. (2011) formulated the BSP with uncertain vessel arrival and handling times. The objective minimized the total late departures and maximized the length of buffer time. The problem was solved using the algorithm, which was based on SA and Branch-and-Bound Algorithm. Zhen and Chang (2012) formulated a bi-objective BSP, taking into account uncertainties of vessel arrivals and handling times. The first objective minimized the total operational cost, while the second one was directed to maximize the robustness of schedule. The authors presented a heuristic to solve the problem. Golias et al. (2014) proposed an EA for the BSP, capturing uncertainty in vessel arrival and handling times. The model was formulated as a bi-level problem, where the upper level minimized the average total service time of vessels, while the lower level minimized the total range of service times. Legato et al. (2014) studied an integrated tactical and operational BSP, considering uncertainty in vessel arrival and handling times and minimizing the total penalty cost because of deviation from the desired berthing position. Solutions at the tactical level were obtained using SBS, while SA was applied at the operational level.

A number of studies focused on multi-objective BSPs. Moorthy and Teo (2006) formulated a bi-objective BSP, minimizing the total vessel service delays and the connectivity cost. An SA-based algorithm was designed to solve the problem. Imai et al. (2007b) focused on a bi-objective BSP, aiming to minimize:

- the total vessel late departures; and
- the total vessel service time.

An EA was used to solve the problem. Cheong et al. (2008) developed an EA for a multi-objective BSP, aiming to minimize the makespan, waiting time of vessels and degree of deviation from a predetermined priority schedule. Cheong and Tan (2008) studied a similar problem, minimizing the total vessel service time and total vessel delayed departures. The authors developed the multi-objective multi-colony ant algorithm to solve the problem. Golias et al. (2009) presented a multi-objective BSP formulation, considering various vessel priority agreements and minimizing the total vessel service time for each vessel priority group. Hu (2015b) formulated a bi-objective BSP, minimizing:

- the total delayed workload; and
- the total night workload.

An EA was developed to solve the problem. Han et al. (2015) proposed a two-phase model for the BSP and the quay crane assignment problem. The objective of the first phase minimized the total vessel waiting time and the total additional time due to deviation from the desired berthing position. The second phase had two objectives:

1. minimize the range of maximum and minimum quay cranes; and
2. minimize the movements of quay cranes.

A PSO algorithm was designed to solve the problem.
The review of literature suggests that BSP receives an increasing attention from the community. However, the majority of studies rely on the stochastic search algorithms without considering any specific problem properties and applying any guided search heuristics (Bierwirth and Meisel, 2015). The contributions of this study to the state-of-the-art include the following:

- This study proposes a novel MA, which applies a local search heuristic for the chromosomes and population initialization and a deterministic parameter control strategy for more efficient exploration and exploitation of the search space.
- Performance of the developed MA is assessed against the exact optimization approaches for the small-size problem instances.
- The proposed solution algorithm is evaluated against the other state-of-the-art metaheuristic algorithms (including a typical EA, VNS and SA) for the realistic-size problem instances.
- A comparative analysis of the solution algorithms is performed not only for a discrete berthing layout case (which is commonly used in the BSP literature) but also for a continuous berthing layout case.

The developed solution algorithm is expected to assist the MCT operators with design of cost-effective berth schedules and reduce potential delays, associated with the vessel service.

3. Problem description

This study models the MCT with a discrete berthing layout (Figure 1). The terminal's wharf is partitioned in several berths, and one vessel can be moored at each berth at the time. The MCT operator is assumed to have the information regarding the vessel arrival times (i.e. dynamic vessel arrival case). The uncertainty in vessel arrival times is not modeled in this study. Once a vessel arrives at the MCT, it is to be towed to the assigned berth by push boats. If the assigned berth is not available (i.e. it is occupied by the other vessel), a vessel will be waiting for service in the dedicated area, located close to the MCT (Figure 1). It is assumed that the safety distance requirements between vessels, moored along the MCT's wharf, are satisfied. The vessels are served using a gang of quay cranes. The container handling productivity (measured in twenty-foot equivalent units [TEUs] per hour) is negotiated with a liner shipping company and is known before the vessel arrives at the MCT.

The container handling charges are imposed to the liner shipping company for each TEU handled. The handling time of a given vessel (measured in hours) is estimated based on the total number of TEUs handled and the handling productivity requested. The uncertainty in vessel handling time due to potential disruptions in the MCT operations is not considered. However, if a given vessel is diverted for the service from the originally scheduled berth (i.e. “preferred berth”) to the other berth (to decrease the waiting time of that vessel), its handling time will increase proportionally to the distance between the actual and desired berthing positions (Bierwirth and Meisel, 2015). The increase in vessel handling time can be explained by the fact that the travel distance from the “preferred berth” to the assigned storage area in the marshaling yard is smaller compared to the travel distance from the other MCT berths.

An additional charge will be imposed to the MCT operator due to vessel waiting for service in the dedicated area. Furthermore, for each vessel, the liner shipping company requests a certain departure time, and violations owing to the difference between the actual and requested departure times will be penalized. If a vessel leaves the MCT before the requested departure time, the liner shipping company will pay the premium to the MCT
operator (Dulebenets, 2015a). The objective of the MCT operator is to design an efficient berth schedule by minimizing the total vessel service cost.

4. Mathematical model
This section presents notations that will be used throughout the paper and a mixed-integer nonlinear mathematical model for the discrete dynamic BSP (DDBSP) studied herein.

Sets
\( V = \{1, \ldots, N\} \) = set of vessels to be served at the MCT; and
\( B = \{1, \ldots, K\} \) = set of berths at the MCT.

Decision variables
- \( x_{vb}, v \in V, b \in B \) = 1 if vessel \( v \) is served at berth \( b \) (= 0 otherwise);
- \( y_{uv}, u, v \in V, u \neq v \) = 1 if vessel \( u \) is served at the same berth immediately after vessel \( v \) (= 0 otherwise);
- \( f_v, v \in V \) = 1 if vessel \( v \) is served as the first vessel at the assigned berth (= 0 otherwise); and
- \( l_v, v \in V \) = 1 if vessel \( v \) is served as the last vessel at the assigned berth (= 0 otherwise).

Auxiliary variables
- \( ST_v, v \in V \) = start time of service for vessel \( v \) (hours);
- \( WT_v, v \in V \) = waiting time of vessel \( v \) (hours).
$ED_v, v \in V$ = hours of early departure for vessel $v$ (hours); and  
$LD_v, v \in V$ = hours of late departure for vessel $v$ (hours);

Parameters  
$A_v, v \in V$ = arrival time of vessel $v$ (hours);  
$NC_v, v \in V$ = number of containers assigned to vessel $v$ (TEUs);  
$hp_v, v \in V, b \in B$ = handling productivity for vessel $v$ at berth $b$ (TEUs per hour);  
$HT_v = \frac{NC_v}{hp_v}, v \in V, b \in B$ = handling time of vessel $v$ at berth $b$ (hours);  
$RD_v, v \in V$ = requested departure time of vessel $v$ (hours);  
$c_H^v, v \in V$ = handling cost for vessel $v$ (US$ per TEU);  
$c_W^v, v \in V$ = waiting cost for vessel $v$ (US$ per hour);  
$c_{ED}^v, v \in V$ = penalty for early departure of vessel $v$ (US$ per hour); and  
$M = $ large positive number.

DDBSP:  
$$
\min \left[ \sum_{v \in V} (NC_v c_H^v) + \sum_{v \in V} (WT_v c_{WT}^v) + \sum_{v \in V} (LD_v c_{LD}^v) - \sum_{v \in V} (ED_v c_{ED}^v) \right] 
$$

Subject to:  
$$
\sum_{b \in B} x_{vb} = 1 \forall v \in V
$$

$$
f_{\bar{v}} + \sum_{\bar{v} \in V, \bar{v} \neq \bar{v}} y_{\bar{v}} = 1 \forall \bar{v} \in V
$$

$$
l_{\bar{v}} + \sum_{\bar{v} \in V, \bar{v} \neq \bar{v}} y_{\bar{v}} = 1 \forall \bar{v} \in V
$$

$$
f_{\bar{v}} + f_{\bar{v}} \leq 3 - x_{\bar{v}b} - x_{\bar{v}b} \forall \bar{v}, \bar{v} \in V, \bar{v} \neq \bar{v}, b \in B
$$

$$
l_{\bar{v}} + l_{\bar{v}} \leq 3 - x_{\bar{v}b} - x_{\bar{v}b} \forall \bar{v}, \bar{v} \in V, \bar{v} \neq \bar{v}, b \in B
$$

$$
y_{\bar{v}} - 1 \leq x_{\bar{v}b} - x_{\bar{v}b} \leq 1 - y_{\bar{v}} \forall \bar{v}, \bar{v} \in V, \bar{v} \neq \bar{v}, b \in B
$$

$$
ST_v \geq A_v \forall v \in V
$$

$$
ST_v \geq ST_v + \sum_{b \in B} (HT_v x_{vb}) - M(1 - y_{\bar{v}}) \forall \bar{v}, \bar{v} \in V, \bar{v} \neq \bar{v}
$$
In DDBSP, the objective function (1) aims to minimize the total service cost of vessels, which includes four components:

1. the total vessel handling cost;
2. the total vessel waiting cost;
3. the total penalty due to late vessel departures; and
4. the total premium due to early vessel departures (which is a negative cost component).

Constraint set (2) ensures that each vessel should be served once at one of the available MCT berths. Constraint set (3) indicates that each vessel is either served first or after another vessel at the given berth. Constraint set (4) ensures that each vessel is either served last or before another vessel at the given berth. Constraint set (5) indicates that only one vessel is served first at each berth of the MCT. Constraint set (6) ensures that only one vessel is served last at each berth of the MCT. Constraint set (7) indicates that a vessel can be served after another, if they are both assigned to the same berth of the MCT. Constraint set (8) ensures that service of a vessel starts only after its arrival. Constraint set (9) estimates start service time of each vessel. Constraint sets (10), (11) and (12) calculate waiting time, hours of late departure and hours of early departure for each vessel served at the MCT, respectively. Constraint sets (13)-(15) define ranges of variables and parameters in the DDBSP model.

Nonlinearity of the DDBSP mathematical model stems from constraint set (12). Note that replacing constraint set (12) with constraint set \( ED_v \geq RD_v - \left[ ST_v + \sum_{b \in B} (HT_{vb} x_{vb}) \right] \), which is similar to inequality (11) that is used for estimating the late vessel departures, will make the solution to the problem unbounded (i.e., \( ED_v \) will be set to infinity “\( \infty \)” for each vessel \( v \), as the objective function of the DDBSP mathematical model minimizes the total service cost of vessels, and the total premium due to early vessel departures is treated as a negative cost component). Therefore, an alternative approach should be applied to linearize the DDBSP mathematical model (i.e., additional constraint sets will be required in the DDBSP mathematical model). Let \( z_{ED}^v = 1 \) if vessel \( v \) departs before
the requested departure time based on the suggested berth schedule (= 0 otherwise). Denote \( ED_{v}^{\text{aux}} \), \( v \in V \) as an auxiliary variable for estimating early vessel departures. Then, the original mixed-integer nonlinear DDBSP mathematical model can be reformulated as a mixed-integer linear mathematical model, which will be further referred to as DDBSP-L, as follows:

\[
\text{DDBSP-L:}\quad \min \left[ \sum_{v \in V} \left( NC_{v} c_{v}^{H} \right) + \sum_{v \in V} \left( WT_{v} c_{v}^{WT} \right) + \sum_{v \in V} \left( LD_{v} c_{v}^{LD} \right) - \sum_{v \in V} \left( ED_{v} c_{v}^{ED} \right) \right] \tag{16}
\]

Subject to:

Constraint sets: (2)-(11), (13)-(15)

\[
ED_{v} \geq RD_{v} - \left[ ST_{v} + \sum_{b \in B} \left( HT_{vb} x_{vb} \right) \right] \quad \forall v \in V \tag{17}
\]

\[
ED_{v}^{\text{aux}} \leq M z_{v}^{ED} \quad \forall v \in V \tag{18}
\]

\[
ED_{v}^{\text{aux}} \leq ED_{v} + M \left( 1 - x_{v}^{ED} \right) \quad \forall v \in V \tag{19}
\]

The objective function (16) of the DDBSP-L mathematical model aims to minimize the total service cost of vessels. Constraint sets (17)-(19) estimate the hours of early departure for each vessel served at the MCT. Both DDBSP and DDBSP-L have \( NP \)-hard complexity. However, they can be solved to the global optimality using commercial optimization solvers for small-size problem instances. While the DDBSP mathematical model will require deployment of mixed-integer nonlinear programming solvers (e.g. BARON, AlphaECP, Couenne, DICOPT, Knitro), the DDBSP-L mathematical model can be solved using mixed-integer linear programming solvers (e.g. CPLEX, Gurobi, FICO-Xpress, MOSEK). A comparative analysis of the DDBSP and DDBSP-L mathematical models in terms of the computational time, required to solve the models, will be conducted in the numerical experiments section (details will be discussed in Section 6.3). Section 5 describes the solution algorithm, which will be used to solve the realistic-size problem instances of the DDBSP and DDBSP-L mathematical models.

5. Solution methodology

As discussed in Section 2, BSPs can be reduced to the machine scheduling problems, which are known to be \( NP \)-hard (Pinedo, 2008). Unlike many of published to-date BSP studies that mostly relied on the stochastic search algorithms, this paper proposes a MA with a deterministic parameter control (MA-DPC) to solve DDBSP (and its linearized version – DDBSP-L) for the realistic-size problem instances. Along with the stochastic search operators, MAs use local search heuristics, which typically improve the objective function value at termination and convergence pattern of the algorithm, as compared to canonical EAs and other stochastic search algorithms. Furthermore, application of the parameter control strategies allows better exploration and exploitation of the search space (Eiben and Smith, 2003). The main steps of the developed MA-DPC are outlined in Procedure 1.
**Procedure 1.** Memetic algorithm with a deterministic parameter control (MA-DPC)

**MA-DPC** (Input Data, PopSize, MutSteps, MutValues, StopCriterion)

**Input:** Input Data - values of the DDBSP parameters; PopSize - population size; MutSteps and MutValues - parameters of the piecewise function for the custom operator; StopCriterion - stopping criterion

**Output:** BestChrom - the best vessel schedule

1. |Pop| ← PopSize; |Fit| ← PopSize; |Parents| ← PopSize; |Offspring| ← PopSize
2. Chrom ← FCFS(InputData) << Chromosome initialization
3. gen ← 0
4. Popgen ← InitPop(Chrom, PopSize) << Population initialization
5. Fitgen ← Evaluate(Popgen, InputData) << Initial population fitness evaluation
6. while StopCriterion ← FALSE do
   7. gen ← gen + 1
   8. Parentsgen ← SelectParents(Popgen) << Select parents
   9. Offspringgen ← MA-DPCoper(Parentsgen, MutSteps, MutValues) << Produce offspring
   10. Fitgen ← Evaluate(Offspringgen, InputData) << Offspring fitness evaluation
   11. Popgen+1 ← Select(Offspringgen, Fitgen) << Define population in the next generation
7. endwhile
8. return BestChrom

In Step 1, data structures for the algorithmic variables are initialized. In Steps 2-4, MA-DPC uses a local search heuristic for the chromosomes and population initialization. In Step 5, the fitness function values are estimated for the initial population chromosomes. Next, MA-DPC enters the main loop (Steps 6 through 12). In Step 8, function **SelectParents(Popgen)** chooses parents from the current population (i.e. variable Parentsgen) that will be used in Step 9 and produce the new offspring. In Step 9, function **MA-DPCoper(Parentsgen, MutSteps, MutValues)** applies a custom operator with a deterministic parameter control to produce the new offspring (i.e. variable Offspringgen). In Step 10, function **Evaluate(Offspringgen, InputData)** computes the values of fitness function (i.e. variable Fitgen) for the offspring chromosomes. In Step 11, function **Select(Offspringgen, Fitgen)** chooses the individuals based on their fitness that will become candidate parents in the following generation. Once the termination criterion is satisfied, MA-DPC exits the loop and returns the best chromosome (BestChrom), which represents the berth schedule with the least vessel service cost. A detailed description of the key algorithmic steps is presented next.

### 5.1 Chromosome representation

An integer chromosome representation is adopted in this paper to represent a solution (i.e. assignment of vessels to berths at the MCT). Each chromosome is composed of genes, which represent vessel identifiers (identifiers are denoted with integers). Note that such terms as vessel assignment, chromosome and individual will be used interchangeably throughout the paper. An example of a chromosome is presented in Figure 2, where 8 vessels request service at the MCT with two berths. Vessels “2”, “4”, “3” and “6” are served at berth “1” (in that order), while vessels “1”, “5”, “8”, and “7” are served at berth “2” (in that order). The length of chromosomes remains fixed throughout the MA-DPC evolution.
5.2 Chromosome/population initialization

Typically EAs rely on randomly initialized chromosomes; however, randomly initialized chromosomes and populations may contain a significant portion of low-quality and infeasible individuals, which may negatively affect the objective function value at termination and convergence pattern of the algorithm (Eiben and Smith, 2003; Sivanandam and Deepa, 2008). The algorithm, proposed in this study, applies a local search heuristic (which makes the algorithm memetic) to initialize the chromosomes. The heuristic is based on the first-come-first-served (FCFS) policy, widely used by the MCT operators in practice (Imai et al., 2008; Golias et al., 2009; Dulebenets, 2015a). Denote VS as the set of vessels sorted based on their arrival times; BA_b as the time when berth b becomes available for the first time in the planning horizon; BP_b as the berthing positions at berth b; ST_v and FT_v as the start and finish service times of vessel v, respectively. The main steps of the FCFS heuristic are presented in Procedure 2.

Procedure 2. First-come-first-served (FCFS) policy

```plaintext
FCFS(V, B, A_v, HT_v)
```

**Input:**
- V = {1,...,N} - set of vessels;
- B = {1,...,K} - set of berths;
- A_v - arrival time of vessel v;
- HT_v - handling time of vessel v at berth b

**Output:**
- BP - vessel positions at each berth
- VS - Sort(V, A) - Sort vessels based on their arrival times in the ascending order

1: Initialization

2: VS ← Sort(V, A)  // Sort vessels based on their arrival times in the ascending order

3: v ← 1
4: for all v ∈ VS do
5: \( b ← \arg\min_b (B_A_b) \)  // Find the first available berth
6: \( BP_b ← BP_b \cup \{v\} \)  // Assign a vessel to that berth
7: \( ST_v ← \max(A_v; BA_b) \)  // Estimate vessel start service time
8: \( FT_v ← ST_v + HT_v \)  // Estimate vessel finish service time
9: \( BA_b ← FT_v \)  // Update berth availability
10: v ← v + 1
11: end for
12: return BP

The initial population is constructed using the identical chromosomes. Various sizes of the initial population (PopSize) will be evaluated during the MA-DPC parameter tuning, and details will be discussed in Section 6. The population size is assumed to be constant and equal to the initial population size throughout the MA-DPC evolution.

5.3 Parent selection

The main objective of the parent selection procedure is to identify the chromosomes (i.e. “parents”) that will be selected to produce the offspring during the MA-DPC operations. This study adopts a deterministic parent selection scheme, which allows all individuals survived in the previous generation to become parents in the next generation. Such parent selection scheme is widely used in evolutionary programming (Eiben and Smith, 2003).

**Figure 2.**
Chromosome representation

<table>
<thead>
<tr>
<th>Berth</th>
<th>1 1 1 1 1 1 1 1 1 2 2 2 2 2 2 2 2 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vessel</td>
<td>2 4 3 6 0 0 0 0 1 5 8 7 0 0 0 0</td>
</tr>
</tbody>
</table>
5.4 MA-DPC operations
Crossover and mutation operators are commonly used for the EA/MA operations. However, for the proposed chromosome representation (Figure 2), typical crossover operators (e.g., one-point crossover, two-point crossover) may cause a complex infeasibility, as some offspring can inherit genes that represent the same vessels. Infeasible individuals may be repaired; however, the latter may incur a substantial computational time. To avoid a potential increase in time complexity of the algorithm, this study will use mutation only. Several types of mutation operators have been used in the past (Eiben and Smith, 2003): swap, invert, scramble, insert, etc. The swap mutation operator will be adopted in this study due to its efficiency for the chromosomes with integer representation (Golias et al., 2009; Dulebenets, 2015a). An example of the swap mutation is presented in Figure 3, where vessels “5” and “8” (originally scheduled at berth “2”) are switched with vessels “2” and “3” (originally scheduled at berth “1”), respectively.

The number of genes, swapped in each chromosome, is typically defined by the mutation rate ($\text{MutRate}$) in canonical EAs and MAs. However, this study uses MA-DPC with a deterministic parameter control for the mutation operator, where $\text{MutRate}$ is no longer a predefined parameter. Specifically, the custom mutation operator, deployed within the MA-DPC algorithm, changes $\text{MutRate}$ throughout the MA-DPC evolution based on values of the piecewise function in a given generation. Denote $I$ as a set of segments in the piecewise function; $\text{MutRate}_{\text{gen}}^i$ as a value of $\text{MutRate}$ in generation $\text{gen}$, suggested by the piecewise function; $\text{MutValues}_i$ as a $\text{MutRate}$ value at segment $i$ in the piecewise function; and $\text{MutSteps}_i$ as a $\text{gen}$ value at the beginning of segment $i$ in the piecewise function. Then, the mutation rate $\text{MutRate}_{\text{gen}}^i$ in generation $\text{gen}$ that will be set by the MA-DPC mutation operator can be estimated using the following equation:

$$\text{MutRate}_{\text{gen}}^i = \text{MutValues}_i : \text{MutSteps}_i < \text{gen} < \text{MutSteps}_{i+1}$$  \hspace{1cm} (20)

An example of the piecewise function for the custom mutation operator with $\text{MutSteps} = [0; 500; 1,000; 1,500; 2,000]$ and $\text{MutValues} = [8; 6; 4; 2]$ is presented in Figure 4. For instance, the custom mutation operator will set $\text{MutRate} = 6$ in generation $\text{gen} = 700$ (Figure 4, segment $i = 2$ of the piecewise function). Setting high $\text{MutRate}$ values at the beginning of the
MA-DPC run allows better exploration of the search space, while decreasing MutRate values towards the MA-DPC convergence allows exploiting the promising domains (Eiben and Smith, 2003). Note that throughout the MA-DPC operations, the custom mutation operator is applied to each individual in the population. Along with the deterministic parameter control strategy, there exist the other alternatives for the parameter control (i.e. adaptive parameter control and self-adaptive parameter control – Eiben and Smith, 2003), which can be explored as a part of the future research.

5.5 Fitness function
The fitness function is typically associated with the objective function in EAs/MAs (Sivanandam and Deepa, 2008). In the developed MA-DPC, the fitness function is set equal to the objective function. No scaling mechanisms were applied to the fitness function.

5.6 Offspring selection
Offspring selection determines the individuals that will survive in the given generation and will become candidate parents in the next generation. This study will use a tournament selection mechanism, which has two parameters:

1. tournament size (TourSize) – number of individuals participating in each tournament; and
2. individuals selected (IndSel) – number of individuals selected based on their fitness at each tournament to become candidate parents in the next generation.

The tournament selection mechanism is based on multiple tournaments. During each tournament, a certain portion of individuals (TourSize) are randomly selected from the population. Then, a set of the best individuals (i.e. individuals with the highest fitness) are chosen from the tournament (a total of IndSel individuals) to become parents in the next generation. The tournament selection mechanism continuously performs tournaments until the desired population size is reached. The total number of tournaments (NumTour), required to obtain the desired population size, can be computed as follows: $NumTour = \frac{PopSize}{IndSel}$ (i.e. ratio of the desired population size to the total number of individuals chosen at one tournament). Various values of the offspring selection parameters will be evaluated during the MA-DPC parameter tuning and details will be discussed in Section 6. The elitist strategy is applied in the developed MA-DPC to ensure that the best individual lives more than one generation (Eiben and Smith, 2003).

5.7 Stopping criterion
The proposed MA-DPC will be terminated once the maximum number of generations (LastGen) is reached. The value of LastGen will be determined based on the preliminary MA-DPC runs (see Section 6 for details).

6. Computational experiments
This section presents a number of computational experiments that were conducted to assess efficiency of the developed MA-DPC in terms of computational time and solution quality. The proposed MA-DPC will be compared against the following alternative algorithms:

- MA that applies the FCFS heuristic for the chromosomes and population initialization, but does not apply the deterministic parameter control strategy for the mutation operator;
• typical EA that initializes the chromosomes and population randomly (i.e., without using any local search heuristics) and does not apply the deterministic parameter control strategy for the mutation operator;
• SA; and
• VNS.

Both SA and VNS algorithms can be considered as advanced state-of-the-art metaheuristic algorithms that have been widely used for solving BSP problems (as discussed in the literature review section). For a detailed description of the SA and VNS algorithms this study refers to Emde and Boysen (2016) and Hansen et al. (2008), respectively. The MA-DPC, MA, EA, SA and VNS algorithms were coded using MATLAB 2016a and executed on a CPU with Dell Intel(R) Core(TM) i7 Processor and 32 GB of RAM. The next sections of the paper elaborate on the input data used, parameter tuning, optimality gap analysis, algorithmic performance and comparative analysis of the developed algorithms for the continuous berthing layout case.

6.1 Input data
The numerical data, required for the computational experiments, were generated based on the available MCT literature (Imai et al., 2007a, 2007b, 2008, 2013; Golias et al., 2009; Dulebenets, 2012; Zampelli et al., 2014; Dulebenets, 2015a, 2015b; Dulebenets, 2016a, 2016b, 2016c; Dulebenets et al., 2016; The Port Authority of New York and New Jersey, 2016; Dulebenets and Ozguven, 2017) and are presented in Table I. A planning horizon of two weeks was modeled in this study. The berthing capacity (BC) at the MCT varied from two berths to four berths with an increment of one berth. A total of four vessel interarrival patterns (A1-4), varying from 2 h to 3 h, and following the exponential distribution (Imai et al., 2007a, 2007b, 2008, 2013) were considered. The number of containers to be handled for each vessel was assigned as $NC_v = U[500; 2,000]$ for each vessel. The handling productivity ($hp_{vb}$, $v \in V, b \in B$) at the preferred berth was set to 125 TEUs per hour. Note that the preferred berth was identified based on the FCFS policy for each vessel. If a given vessel was diverted for service from the preferred berth to the other berth, the handling productivity was decreased proportionally to the distance between the actual and desired berthing positions (Bierwirth and Meisel, 2015). The requested departure time of a vessel was assigned based on the vessel arrival time and

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning horizon</td>
<td>2 weeks</td>
</tr>
<tr>
<td>Number of berths at the MCT: [BC1; BC2; BC3]</td>
<td>[2; 3; 4]</td>
</tr>
<tr>
<td>Vessel interarrival patterns – exponential: [A1; A2; A3; A4] (hours)</td>
<td>[2.0; 2.3; 2.7; 3.0]</td>
</tr>
<tr>
<td>Containers assigned to each vessel: $NC_v, v \in V$ (TEUs)</td>
<td>$U[500; 2,000]$</td>
</tr>
<tr>
<td>Handling productivity at the preferred berth: $hp_{vb}, v \in V, b \in B$ (TEUs per hour)</td>
<td>125</td>
</tr>
<tr>
<td>Requested vessel departure: $RD_v, v \in V$ (hours)</td>
<td>$RD_v = A_v + HT_{vb} \cdot U[1.0; 1.2]$</td>
</tr>
<tr>
<td>Vessel handling cost: $c_H^v, v \in V$ (US$ per TEU)</td>
<td>$U[400; 600]$</td>
</tr>
<tr>
<td>Vessel waiting cost: $c_{WT}^v, v \in V$ (US$ per hour)</td>
<td>$U[1,500; 2,500]$</td>
</tr>
<tr>
<td>Early departure premium: $c_{ED}^v, v \in V$ (US$ per hour)</td>
<td>$U[4,000; 6,000]$</td>
</tr>
<tr>
<td>Late departure penalty: $c_{LD}^v, v \in V$ (US$ per hour)</td>
<td>$U[6,000; 8,000]$</td>
</tr>
</tbody>
</table>

Table I. Numerical data
the handling time at the preferred berth. Based on the available literature (Zampelli et al., 2014; The Port Authority of New York and New Jersey, 2016), the vessel handling cost was generated as $c_H^v = U[400; 600] \forall v \in V$ (US$ per TEU), while the vessel waiting cost was initialized as $c_W^v = U[1,500; 2,500] \forall v \in V$ (US$ per hour). The early departure premium and late departure penalty were generated as $c_{ED}^v = U[4,000; 6,000] \forall v \in V$ (US$ per hour) and $c_{LD}^v = U[6,000; 8,000] \forall v \in V$ (US$ per hour), respectively (Zampelli et al., 2014).

Based on the generated numerical data, a total of 30 problem instances were developed, which can be classified into the following two groups:

1. Small-size problem instances, which were generated by changing the berthing capacity at the MCT (i.e. BC1, BC2, BC3) and the number of vessels calling for service at the MCT (from 6 to 16 with an increment of 2 vessels), assuming frequent vessel arrivals (i.e., vessel interarrival pattern A1) — [3 berthing capacity scenarios] $\times$ [6 vessel call types] $= 18$ problem instances (that will be referred to as S1-S18); and

2. Realistic-size problem instances, which were generated by changing the berthing capacity at the MCT (i.e. BC1, BC2, BC3) and the vessel interarrival patterns (i.e., A1, A2, A3, A4) — [3 berthing capacity scenarios] $\times$ [4 vessel interarrival patterns] $= 12$ problem instances (that will be referred to as R1-R12).

Note that the small-size problem instances will be used for the optimality gap analysis of the developed algorithms (which will be described in Section 6.3 of the paper), while the realistic-size problem instances will be used for the comprehensive evaluation of the developed algorithms in terms of the objective function values at termination, computational time and convergence patterns (which will be described in Section 6.4 of the paper).

6.2 Parameter tuning
As mentioned in the beginning of Section 6, efficiency of the proposed MA-DPC will be evaluated based on a comparative analysis against the MA, EA, SA, and VNS algorithms. The developed algorithms have several parameters that have to be determined based on the parameter tuning analysis (Eiben and Smith, 2003). A total of three problem instances were randomly selected from the generated 12 realistic-size problem instances for the parameter tuning. For each instance, a total of 600 possible parameter combinations were tested for MA-DPC, considering the following candidate values of parameters: $\text{PopSize} = [20; 30; 40; 50; 60], |l| = [2; 3; 4], \text{MutValues} = [2; 4; 6; 8; 10], \text{MutSteps}_{i+1} = \text{MutSteps}_i + \frac{\text{LastGen}}{|l|}, \text{TourSize} = [0.5 \cdot \text{PopSize}; 0.6 \cdot \text{PopSize}]$ and $\text{IndSel} = [0.1 \cdot \text{PopSize}; 0.2 \cdot \text{PopSize}]$. As for the MA and EA parameters, for each instance, a total of 100 possible parameter combinations were tested, considering the following candidate values of parameters: $\text{PopSize} = [20; 30; 40; 50; 60], \text{MutRate} = [2; 4; 6; 8; 10], \text{TourSize} = [0.5 \cdot \text{PopSize}; 0.6 \cdot \text{PopSize}],$ and $\text{IndSel} = [0.1 \cdot \text{PopSize}; 0.2 \cdot \text{PopSize}]$. A total of 5 replications were performed to estimate the average values of the objective function and computational time for each combination of parameters, i.e. a total of $600 \times 5 = 3,000$ MA-DPC runs, $100 \times 5 = 500$ MA runs and $100 \times 5 = 500$ EA runs for each problem instance. Throughout the computational experiments, it was noticed that the objective function values did not change significantly after generation $\text{gen} = 2,000$ for the MA-DPC, MA and EA algorithms. Hence, the termination criterion will be set to $\text{LastGen} = 2,000$ generations for those algorithms.
The SA algorithm has a total of three parameters:

1. initial temperature \( T^0 \);
2. temperature interval \( \Delta T \); and
3. maximum number of iterations \( \text{LastIter} \).

For each instance a total of 25 possible parameter combinations were tested for SA, considering the following candidate values of parameters: \( T^0 = [500; 750; 1,000; 1,250; 1,500] \) and \( \Delta T = [0.2; 0.3; 0.4; 0.5; 0.6] \). The VNS algorithm also has a total of three parameters:

1. number of neighborhood structures \( Nstr \);
2. exchange rate \( \text{ExRate} \), i.e. the number of vessels to be swapped in the current solution of a given neighborhood in order to generate a solution in another neighborhood; and
3. maximum number of iterations \( \text{LastIter} \).

For each instance, a total of 25 possible parameter combinations were tested for VNS, considering the following candidate values of parameters: \( Nstr = [20; 30; 40; 50; 60] \) and \( \text{ExRate} = [2; 4; 6; 8; 10] \). A total of five replications were performed to estimate the average values of the objective function and computational time for each combination of parameters, i.e. a total of \( 25 \times 5 = 125 \) runs for both SA and VNS algorithms for each problem instance. Throughout the computational experiments, it was noticed that the objective function values did not change significantly after iteration \( \text{LastIter} = 2,000 \) for the SA and VNS algorithms. Hence, the termination criterion will be set to \( \text{LastIter} = 2,000 \) iterations for those algorithms. Table II shows results of the parameter tuning analysis, where the algorithmic parameter values were selected based on the tradeoff between the computational time and the objective function value at termination.

### 6.3 Optimality gap analysis

The first set of computational experiments focused on estimating the optimality gaps for the developed algorithms to determine how close the solutions, obtained by the algorithms, to the global optimal solutions. The small-size problem instances (S1-S18, described in Section 6.1) were used throughout the optimality gap analysis. The mixed-integer nonlinear DDBSP mathematical model was coded in General Algebraic Modeling System (GAMS) and solved using BARON for all the generated small-size problem instances. The relative optimality gap for BARON was assigned to be 0.1 per cent, while the allowable computational time was restricted to 2 h (or 7,200 s). Note that BARON is widely used in operations research for solving mixed-integer nonlinear mathematical models to the global optimality (Sahinidis, 2017). The MA-DPC, MA, EA, SA, and VNS algorithms were executed for the small-size problem instances as well. A total of five replications were performed for each problem instance to estimate the average objective function and computational time values for each algorithm. Results of the optimality gap analysis are summarized in Table III, where the following data are presented:

- instance number;
- berthing capacity (BC);
- number of vessels calling for service at the MCT (\( |V| \));
- objective function values (denoted as \( Z \)) for each solution approach; and
- computational time values (denoted as CPU) for each solution approach.
The optimality gap for algorithm $a$ ($G_a$) was estimated based on the following relationship:

$$G_a = \frac{Z_a - z_{\text{BARON}}}{z_{\text{BARON}}}$$

The obtained optimality gap values are presented in Figure 5.

It can be observed that due to complexity of the DDBSP mathematical model, BARON computational time was significantly affected with increasing problem size. For certain problem instances (i.e. instance S12 and S18), BARON was not able to provide the global optimal solution within the time limit imposed. The solutions, obtained by BARON for problem instances S12 and S18, were outperformed by the MA-DPC, MA, EA, SA and VNS algorithms in terms of the objective function values on average by 4.04, 3.51, 2.03, 1.82 and 2.31 per cent respectively. For the rest of small problem instances, the maximum optimality gap values comprised 0.46, 0.72, 1.94, 2.39 and 1.98 per cent for the MA-DPC, MA, EA, SA and VNS algorithms, respectively, which showcase a high accuracy of the developed algorithms. Furthermore, results indicate that the proposed MA-DPC, which applies a deterministic parameter control strategy, provided superior objective function values as compared to the MA, EA, SA and VNS algorithms. Specifically, the MA-DPC objective function value was lower, on average, by 0.19, 0.69, 0.81 and 0.68 per cent as compared to the objective function values, obtained by the MA, EA, SA and VNS algorithms, respectively. The average computational time comprised 48.4 s, 42.6 s, 41.5 s, 9.1 s and 31.7 s, respectively. Lower computational time was required by the SA and VNS algorithms due to

<table>
<thead>
<tr>
<th>Algorithm</th>
<th>Parameter</th>
<th>Adopted value</th>
</tr>
</thead>
<tbody>
<tr>
<td>MA-DPC</td>
<td>Population size: $\text{PopSize}$</td>
<td>50</td>
</tr>
<tr>
<td>MA-DPC</td>
<td>Number of segments in the piecewise function for the custom mutation operator: $</td>
<td>I</td>
</tr>
<tr>
<td>MA-DPC</td>
<td>Mutation rate values at each segment in the piecewise function: $\text{MutValues}$</td>
<td>[6; 4; 2; 2]</td>
</tr>
<tr>
<td>MA-DPC</td>
<td>Generation values at the beginning of each segment in the piecewise function: $\text{MutSteps}$</td>
<td>[0; 500; 1,000; 1,500; 2,000]</td>
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<tr>
<td>MA-DPC</td>
<td>Tournament size: $\text{TourSize}$</td>
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<tr>
<td>MA-DPC</td>
<td>Number of individuals selected at each tournament: $\text{IndSel}$</td>
<td>5</td>
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<td>MA-DPC</td>
<td>Maximum number of generations: $\text{LastGen}$</td>
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</tr>
<tr>
<td>MA</td>
<td>Population size: $\text{PopSize}$</td>
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<tr>
<td>MA</td>
<td>Mutation rate: $\text{MutRate}$</td>
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<tr>
<td>EA</td>
<td>Population size: $\text{PopSize}$</td>
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<td>Mutation rate: $\text{MutRate}$</td>
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<td>EA</td>
<td>Tournament size: $\text{TourSize}$</td>
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<td>Number of individuals selected at each tournament: $\text{IndSel}$</td>
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<td>Maximum number of iterations: $\text{LastIter}$</td>
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<td>VNS</td>
<td>Exchange rate: $\text{ExRate}$</td>
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<tr>
<td>VNS</td>
<td>Maximum number of iterations: $\text{LastIter}$</td>
<td>2,000</td>
</tr>
</tbody>
</table>

Table II. Parameter tuning analysis results

The optimality gap for algorithm $a$ ($G_a$) was estimated based on the following relationship:

$$G_a = \frac{Z_a - z_{\text{BARON}}}{z_{\text{BARON}}}$$

The obtained optimality gap values are presented in Figure 5.
<table>
<thead>
<tr>
<th>Inst.</th>
<th>BC</th>
<th></th>
<th></th>
<th>BARON</th>
<th>MADPC</th>
<th>MA</th>
<th>EA</th>
<th>SA</th>
<th>VNS</th>
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<tr>
<td>S1</td>
<td>[BC1]</td>
<td>6</td>
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<td>[BC1]</td>
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<td>5.906</td>
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</tr>
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<td>32.22</td>
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<td>342.44</td>
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<td>48.00</td>
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</tr>
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<td>1857.84</td>
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<td>53.25</td>
<td>8.578</td>
<td>46.31</td>
<td>8.578</td>
</tr>
<tr>
<td>S18</td>
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<td>11.504</td>
<td>7202.12</td>
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<td>57.51</td>
<td>11.504</td>
<td>52.08</td>
<td>11.504</td>
</tr>
<tr>
<td>Average</td>
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<td></td>
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<td>7.956</td>
<td>48.40</td>
<td>7.976</td>
<td>42.62</td>
<td>8.027</td>
</tr>
</tbody>
</table>
the fact that those algorithms are not population-based (and, therefore, require less evaluations of the generated solutions).

As discussed in Section 4, the mixed-integer nonlinear DDBSP mathematical model can be linearized to the DDBSP-L mathematical model and solved using mixed-integer linear programming solvers to the global optimality for the small-size problem instances. The scope of computational experiments includes evaluation of both DDBSP and DDBSP-L mathematical models in terms of the computational time, required to solve the models. To accomplish the latter objective, the mixed-integer linear DDBSP-L mathematical model was coded in GAMS and solved using CPLEX for all the generated small-size problem instances. CPLEX is widely used in operations research for solving large-scale mixed-integer linear programming models to the global optimality. The relative optimality gap for CPLEX was restricted to 0.1 per cent, while the allowable computational time was assigned to be 2 h (or 7,200 s). Note that the same settings were established for BARON. The comparative analysis results are illustrated in Figure 6, which presents the computational time, required by BARON and CPLEX to solve the small-size problem instances of the DDBSP and DDBSP-L mathematical models, respectively. Note that BARON and CPLEX were not compared in terms of solution quality, as they returned solutions with the same objective function values (i.e. the global optimal solutions) for the problem instances, which were solved within the time limit imposed. It can be observed that CPLEX was generally able to obtain the optimal solutions faster as compared to BARON. However, owing to the complexity of the DDBSP and DDBSP-L mathematical models, both solution approaches were not able to solve problem instance S18 to the global optimality within the time limit imposed.

6.4 Algorithmic performance

Upon completion of the optimality gap analysis for MA-DPC, MA, EA, SA, and VNS, the algorithms were executed for all 12 developed realistic-size problem instances (R1-R12,
described in Section 6.1). A total of five replications were performed for each problem instance to estimate the average objective function and computational time values for each algorithm. Results are presented in Table IV, including the following information:

- instance number;
- berthing capacity (BC);
- vessel interarrival pattern (A);
- objective function values (denoted as \( Z \)) for each solution approach; and
- computational time values (denoted as CPU) for each solution approach.

Along with the objective function and computational time values, the coefficient of variation of the objective function values was recorded for each algorithm and each problem instance to measure variability in the objective function values at convergence over five replications. The estimated coefficient of variation values are presented in Figure 7 for each algorithm and each instance.

We observe that MA-DPC reduced the total vessel service cost of berth schedules, on average, over all realistic-size problem instances and replications by 4.9, 6.9, 7.2, and 5.4 per cent as compared to the MA, EA, SA and VNS berth schedules, respectively. Furthermore, MA-DPC yielded greater cost savings for the cases with high demand and low MCT berthing capacity (i.e. the average cost savings over the MA, EA, SA and VNS berth schedules for problem instance R1 with BC1 and A1 comprised 12.0, 14.7, 13.5 and 8.0 per cent, respectively). The SA algorithm demonstrated the worst performance in terms of the objective function values at termination. The latter finding can be explained by the fact that SA is a single-solution-based algorithm (unlike the MA-DPC, MA and EA algorithms that are population-based), which limits the SA explorative capabilities. Moreover, the SA initial solution is generated randomly without using any local search heuristic. The VNS algorithm showed a good performance for the problem instances with low MCT berthing capacity and frequent vessel arrivals (i.e. problem instances R1, R5, and R9). The latter can be supported by the fact that VNS allows efficient exploration of various neighborhoods. However, for the rest of problem instances the VNS performance was worsening primarily due to the fact that it is a single-solution-based algorithm.

The coefficient of variation did not exceed 1.6 per cent over all the developed algorithms and considered problem instances, indicating stability of the algorithms. However, lower coefficient of variation values were generally recorded for the MA-DPC algorithm. The average computational time was 222.5 s, 222.7 s, 210.2 s, 98.9 s, and 160.8 s over all the generated realistic-size problem instances and performed replications for the MA-DPC, MA, EA, SA and VNS algorithms, respectively. The SA algorithm incurred the least computational time, as SA evaluates only two solutions at each iteration (i.e. the current solution and the neighbor solution), while VNS requires evaluation of solutions within different neighborhoods at each iteration of the algorithm. On the other hand, MA-DPC, MA and EA evaluate each solution in the given population at each generation, which incurs greater computational time as compared to the SA and VNS algorithms.

Throughout the computational experiments, the convergence patterns of the algorithms were recorded for each replication and each problem instance. Results are presented in Figure 8 for the first replication of all realistic-size problem instances (note that the convergence patterns did not change significantly from one replication to the other for the MA-DPC, MA, EA, SA, and VNS algorithms). We observe that all the developed algorithms provide berth schedules, which are significantly superior to the initial berth schedule (produced based on the FCFS policy) in terms of the total vessel service cost, especially for...
Table IV. Comparison of the developed algorithms for the realistic-size problem instances

<table>
<thead>
<tr>
<th>Inst.</th>
<th>BC</th>
<th>A</th>
<th>MA-DPC Z, 10^6 US$</th>
<th>CPU, s</th>
<th>MA Z, 10^6 US$</th>
<th>CPU, s</th>
<th>EA Z, 10^6 US$</th>
<th>CPU, s</th>
<th>SA Z, 10^6 US$</th>
<th>CPU, s</th>
<th>VNS Z, 10^6 US$</th>
<th>CPU, s</th>
</tr>
</thead>
<tbody>
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<td>R1</td>
<td>[BC1]</td>
<td>[A1]</td>
<td>607.91</td>
<td>264.14</td>
<td>680.58</td>
<td>260.03</td>
<td>697.15</td>
<td>243.02</td>
<td>689.78</td>
<td>101.44</td>
<td>656.14</td>
<td>187.89</td>
</tr>
<tr>
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<td>[BC1]</td>
<td>[A2]</td>
<td>474.68</td>
<td>192.82</td>
<td>502.44</td>
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<td>504.23</td>
<td>179.64</td>
<td>504.92</td>
<td>82.25</td>
<td>503.18</td>
<td>156.36</td>
</tr>
<tr>
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<td>[A3]</td>
<td>414.01</td>
<td>219.21</td>
<td>453.77</td>
<td>218.92</td>
<td>471.90</td>
<td>205.75</td>
<td>475.47</td>
<td>71.11</td>
<td>472.81</td>
<td>132.93</td>
</tr>
<tr>
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<td>[A4]</td>
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<td>168.52</td>
<td>252.24</td>
<td>169.31</td>
<td>261.88</td>
<td>159.12</td>
<td>262.80</td>
<td>61.68</td>
<td>262.23</td>
<td>117.16</td>
</tr>
<tr>
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<td>[A1]</td>
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<td>273.69</td>
<td>399.43</td>
<td>273.29</td>
<td>411.47</td>
<td>257.58</td>
<td>412.55</td>
<td>124.52</td>
<td>397.99</td>
<td>198.70</td>
</tr>
<tr>
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<td>[A2]</td>
<td>296.06</td>
<td>206.50</td>
<td>300.93</td>
<td>208.28</td>
<td>303.25</td>
<td>196.49</td>
<td>304.30</td>
<td>102.82</td>
<td>301.34</td>
<td>165.98</td>
</tr>
<tr>
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<td>[A3]</td>
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<td>233.92</td>
<td>256.70</td>
<td>232.80</td>
<td>260.17</td>
<td>219.62</td>
<td>265.04</td>
<td>89.43</td>
<td>262.19</td>
<td>145.55</td>
</tr>
<tr>
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<td>[BC2]</td>
<td>[A4]</td>
<td>141.98</td>
<td>181.82</td>
<td>143.29</td>
<td>181.99</td>
<td>144.84</td>
<td>171.85</td>
<td>145.61</td>
<td>77.30</td>
<td>145.09</td>
<td>128.44</td>
</tr>
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<td>[A1]</td>
<td>260.26</td>
<td>291.55</td>
<td>261.26</td>
<td>288.44</td>
<td>265.21</td>
<td>272.89</td>
<td>266.65</td>
<td>149.75</td>
<td>264.22</td>
<td>217.55</td>
</tr>
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<td>[A2]</td>
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<td>201.22</td>
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<td>202.05</td>
<td>204.88</td>
<td>202.82</td>
<td>124.06</td>
<td>202.52</td>
<td>181.02</td>
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<td>[A3]</td>
<td>159.44</td>
<td>239.84</td>
<td>161.39</td>
<td>243.36</td>
<td>162.35</td>
<td>231.55</td>
<td>163.77</td>
<td>109.12</td>
<td>163.30</td>
<td>158.04</td>
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<td>[A4]</td>
<td>97.50</td>
<td>187.26</td>
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<td>188.54</td>
<td>97.81</td>
<td>179.56</td>
<td>98.04</td>
<td>92.69</td>
<td>97.96</td>
<td>139.54</td>
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<td>294.79</td>
<td>222.52</td>
<td>309.24</td>
<td>222.71</td>
<td>315.19</td>
<td>210.16</td>
<td>315.98</td>
<td>98.85</td>
<td>310.75</td>
<td>160.76</td>
</tr>
</tbody>
</table>
the instances with low MCT berthing capacity. However, a random initialization of the chromosomes and population negatively affects fitness of individuals within the initial population of the EA, SA and VNS algorithms (based on the convergence patterns, it can be noticed that the initial EA, SA and VNS solutions have greater total vessel service cost as compared to the solutions, constructed based on the FCFS policy).

Moreover, the introduction of the custom mutation operator with a deterministic parameter control allows MA-DPC more efficient exploration and exploitation of the search space. For example, in problem instance R1, both MA-DPC and MA identified solutions with the total vessel service cost of $\approx \text{US}680\text{m}$ in generation $\approx 60$. Afterwards, MA was not able to explore any other domains of the search space due to low mutation rate, which resulted in a local (or “premature”) convergence. However, a high mutation rate in the beginning of the MA-DPC run and lower mutation rate toward the MA-DPC convergence allowed discovering berth schedules with significantly lower vessel service costs. The EA algorithm demonstrated worse performance than MA-DPC and MA, as it solely relies on the stochastic search operators and does not apply any parameter control strategies. As it was mentioned earlier, the VNS and SA algorithms were outperformed by the MA-DPC, MA and EA algorithms for the majority of realistic-size problem instances due to the fact that VNS and SA are single-solution-based algorithms that do not deploy any local search heuristics for initialization of the starting solutions.

Results from the extensive numerical experiments demonstrate that the proposed algorithm, which applies a local search heuristic for the chromosomes and population initialization and a deterministic parameter control strategy, can serve as an efficient planning tool for the MCT operators and assist with construction of cost-effective berth schedules. Furthermore, deployment of a local search heuristic and a custom mutation operator yields greater savings in terms of the total vessel service cost for the cases with high demand and low MCT berthing capacity without significantly affecting the computational time.

6.5 Comparative analysis for the continuous berthing layout case

The scope of computational experiments also includes a comparative analysis of the developed algorithms for the continuous berthing layout. In case of the continuous berthing layout, the wharf is not partitioned into separate berthing positions (as it is assumed in the discrete berthing layout case), and the total number of vessels that can be moored along the wharf is determined based on the their overall length and the wharf’s length (i.e. the overall length of vessels, including safety distances between consecutive vessels, cannot exceed the wharf’s length). The wharf’s length was varied from 3,000 ft. to 6,000 ft. with an increment of 1,500 ft. The length of arriving vessels was set as $l_v = U[950; 1,350] v V (\text{ft.})$, where 950 ft. is a typical length of Panamax vessels, while 1,350 ft. is a typical length of Triple E vessels that are also classified as ultra-large container vessels (Port Technology, 2015). Additional 12 realistic-size problem instances (that will be
referred to as R13-R24) were developed by changing the wharf’s length at the MCT (i.e. 3,000 ft. – [WL1], 4,500 ft. – [WL2] and 6,000 ft. – [WL3]) and the vessel interarrival patterns (i.e. A1, A2, A3, A4). The developed algorithms were executed for additional 12 realistic-size problem instances (R13-R24). A total of five replications were performed for each problem instance to estimate the average objective function and computational time values for each algorithm. Results are presented in Table V, including the following information:
Table V: Comparison of the developed algorithms for the continuous berthing layout case.

<table>
<thead>
<tr>
<th>Inst.</th>
<th>WL</th>
<th>A</th>
<th>MA-DPC Z, 10^6 US$</th>
<th>CPU, s</th>
<th>MA Z, 10^6 US$</th>
<th>CPU, s</th>
<th>EA Z, 10^6 US$</th>
<th>CPU, s</th>
<th>SA Z, 10^6 US$</th>
<th>CPU, s</th>
<th>VNS Z, 10^6 US$</th>
<th>CPU, s</th>
</tr>
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<tbody>
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<td>R13</td>
<td>[WL1]</td>
<td>[A1]</td>
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<td>275.45</td>
<td>438.96</td>
<td>271.30</td>
<td>446.58</td>
<td>258.58</td>
<td>444.93</td>
<td>108.34</td>
<td>424.17</td>
<td>198.22</td>
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<td>202.12</td>
<td>333.80</td>
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<td>334.65</td>
<td>86.20</td>
<td>333.98</td>
<td>162.90</td>
</tr>
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<td>294.96</td>
<td>214.81</td>
<td>293.00</td>
<td>75.45</td>
<td>294.48</td>
<td>141.97</td>
</tr>
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<td>[A4]</td>
<td>221.03</td>
<td>179.52</td>
<td>238.71</td>
<td>178.03</td>
<td>248.63</td>
<td>169.94</td>
<td>248.29</td>
<td>64.52</td>
<td>248.16</td>
<td>125.36</td>
</tr>
<tr>
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<td>[A1]</td>
<td>351.82</td>
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<td>365.77</td>
<td>287.58</td>
<td>377.53</td>
<td>268.91</td>
<td>377.02</td>
<td>132.11</td>
<td>364.87</td>
<td>208.84</td>
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<td>218.38</td>
<td>280.83</td>
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<td>281.02</td>
<td>108.89</td>
<td>278.85</td>
<td>173.45</td>
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<td>[A3]</td>
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<td>248.32</td>
<td>230.60</td>
<td>251.73</td>
<td>94.08</td>
<td>249.43</td>
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<td>200.71</td>
<td>190.64</td>
<td>203.25</td>
<td>179.76</td>
<td>203.41</td>
<td>81.25</td>
<td>202.64</td>
<td>133.70</td>
</tr>
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<td>[WL3]</td>
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<td>305.12</td>
<td>297.38</td>
<td>302.01</td>
<td>301.59</td>
<td>286.26</td>
<td>302.30</td>
<td>159.34</td>
<td>299.93</td>
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</tr>
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<td>R22</td>
<td>[WL3]</td>
<td>[A2]</td>
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<td>229.94</td>
<td>236.65</td>
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<td>237.89</td>
<td>130.14</td>
<td>238.34</td>
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<td>[WL3]</td>
<td>[A3]</td>
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<td>245.67</td>
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<td>115.99</td>
<td>236.24</td>
<td>168.47</td>
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<tr>
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<td>[A4]</td>
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<td>195.53</td>
<td>149.78</td>
<td>196.97</td>
<td>150.06</td>
<td>188.36</td>
<td>150.59</td>
<td>96.39</td>
<td>150.75</td>
<td>145.68</td>
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<tr>
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<td>233.92</td>
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<td>221.51</td>
<td>280.27</td>
<td>104.39</td>
<td>276.82</td>
<td>169.57</td>
</tr>
</tbody>
</table>
instance number;
- wharf’s length (WL);
- vessel interarrival pattern (A);
- objective function values (denoted as $Z$) for each solution approach; and
- computational time values (denoted as CPU) for each solution approach.

The MA-DPC cost savings over the alternative algorithms for the continuous berthing layout case are presented in Figure 9 for realistic-size problem instances R13-R24.

Similar to the results, obtained for the discrete berthing layout case, MA-DPC outperformed the other developed algorithms in terms of solution quality for the continuous berthing layout case. Specifically, the total vessel service cost of the MA-DPC berth schedules was lower, on average, by 5.8, 7.7, 7.8 and 6.5 per cent as compared to the MA, EA, SA and VNS berth schedules, respectively. Therefore, greater cost savings from the MA-DPC berth schedules were obtained for the continuous berthing layout case, as compared to the discrete berthing layout case. Moreover, substantial cost savings were recorded for the problem instances with lower capacity of the wharf and frequent vessel arrivals. The MA-DPC algorithm outperformed the MA, EA, SA and VNS algorithms in terms of the total vessel service cost, on average, by 10.5, 13.5, 13.2 and 11.8 per cent, respectively, for realistic-size problem instances R13-R16. The computational time of the developed algorithms was greater for the continuous berthing layout case, as compared the discrete berthing layout case. However, the increase in the average computational time did not exceed 6.3 per cent over the considered algorithms. Thus, the proposed MA-DPC algorithm will assist the MCT operators with efficient berth planning for both discrete and continuous berthing layout cases.

7. Conclusions and future research extensions
MCT operators have to seek new strategies that will allow to meet the growing demand for containerized trade and in the meantime coping with the existing congestion issues. This paper focused on improving the seaside operations of MCTs and proposed a novel MA with a deterministic parameter control to ensure efficiency of berth schedules by minimizing the total vessel service cost. Unlike published to-date berth scheduling studies that mostly rely on the stochastic search algorithms, the developed algorithm applied a local search heuristic for the chromosomes and population initialization and adjusted the mutation rate values based on a deterministic parameter control strategy. A set of computational experiments were performed to assess efficiency of the proposed MA with a deterministic parameter control based on a comprehensive comparative analysis against the alternative state-of-the-art solution algorithms widely used in the berth scheduling literature.

![Figure 9. MA-DPC cost savings over the alternative algorithms](image-url)
Results demonstrated that the developed MA with a deterministic parameter control was able to obtain superior berth schedules in terms of the total vessel service cost within a reasonable computational time. Furthermore, greater cost savings were observed for the cases with high demand and low berthing capacity at the terminal. A comprehensive analysis of the convergence patterns indicated that the introduction of the custom mutation operator with a deterministic control for the mutation rate value would provide more efficient exploration and exploitation of the search space. Moreover, a set of additional computational experiments indicated that cost savings from the application of the proposed solution algorithm would be even greater in the case of the continuous berthing layout.

Future research may focus on the following extensions:

- apply the proposed algorithm for the realistic operational data, collected from MCTs;
- develop local search heuristics for the MA-DPC operations;
- consider adaptive and self-adaptive operators within the proposed algorithm;
- evaluate alternative convergence criteria;
- model the vessel draft requirements;
- evaluate performance the proposed solution algorithm for the alternative berthing layouts (e.g., hybrid berthing layout, indented berthing layout, channel berthing layout); and
- perform a comprehensive comparative analysis of the developed MA-DPC algorithm against other algorithms, reported in the berth scheduling literature (i.e. Tabu search, particle swarm optimization, greedy randomized adaptive search procedure and others).

References


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Leader-member exchange, safety climate and employees’ safety organizational citizenship behaviors in container terminal operators

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Abstract

Purpose – Container terminal operation is one of the most risky industries. Many of the accidents that occurred were found to be caused by human errors. However, it seems relatively little research has been conducted to examine the influence of leader-member exchange (LMX) relationship on employee safety behavior. Therefore, the purpose of this study is to examine the effects of leader-member exchange and safety climate on employees’ safety organizational citizenship behaviors (SOCB) in the container terminal context based on the social exchange theory.

Design/methodology/approach – A structural equation modeling was used with confirmatory factor analysis, and survey data are collected from 265 employees in major container terminals in Taiwan.

Findings – Results indicated that LMX is positively associated with safety climate, whereas safety climate positively influences employees’ safety citizenship behavior. Specifically, results indicated that safety climate mediates the effect of LMX on employees’ SOCB.

Research limitations/implications – This study was limited to LMX dimensions adapted from the studies of Li and Liao (2014) and Vidyarthi et al. (2014). Future research could examine the linkages between LMX, ethical climate, safety performance and supervisor leadership influence. Furthermore, this research focused specifically on employees from the container terminal operators in Taiwan. It would be valuable to collect data from employees from other countries to obtain a balanced view of the relationship between LMX, team-member exchange (TMX), safety climate and employee SOCB in container terminal operations.

Practical implications – This research provides a useful implication for container terminal operators to enhance LMX qualities and employee safety behavior through organizational participation, employee-helping behaviors and informing workers to obey safety rule and regulation.

Originality/value – Given the prevalence of accidents and unsafe behavior in container terminal operations, this research sought to examine the relationships among LMX, safety climate and employee SOCB in the container terminal context. Theoretically, this study highlights the importance of LMX and safety climate in explaining the SOCB of employees.

Keywords Safety climate, Container terminal, Leader-member exchange, Safety organizational citizenship behaviour

Paper type Research paper

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1. Introduction
Safety is always a concern in the operations of container terminal and maritime transport. Despite that, there are thousands of fatalities in maritime accidents, many losses of vessels and billions of dollars in marine claims (Talley et al., 2006; Talley et al., 2008). Several reports and studies indicate that about 75-96 per cent of most maritime casualties are attributed to human errors (Lu and Tsai, 2010; Rothblumr, 2000; Ung and Shen, 2011). The causes of crew injuries or fatalities and vessel accidents are not always clear. Given these reasons, researchers have devoted much effort to examine safety behaviors.

A majority of previous studies have proposed that safety climate can help to predict safety-related outcomes, such as accidents or injuries (Brown and Holmes, 1986; Dedobbeleer and Beland, 1991; DeJoy, 1994; Diaz and Cabrera, 1997; Gillen et al., 2002; Glendon and Litherland, 2001; Lu and Tsai, 2010; Lu and Yang, 2011; Zohar, 1980). Safety climate refers to “the shared perceptions of the employees concerning practices, procedures, and the kind of behavior that get rewarded, supported and expected in a setting”. Safety Climate is a specific form of organizational climate, which is defined as “shared perceptions about organizational values, norms, beliefs, practices and procedures” (Guldenmund, 2000). Neal et al. (2000) found safety climate influenced self-reported components of safety performance. Katz-Navon et al. (2005) suggested that the notion of safety climate explained the occurrence of treatment errors in health care. Their research results demonstrated that perceived safety procedures and clear information flow were effective on reducing treatment errors. Lu and Tsai (2010) empirically examined safety climate and its effects on safety behaviors from the perceptions of seafarers in the context of container shipping. Safety policy and perceived supervisory safety behavior were shown to have a significant direct impact on safety behavior. Furthermore, Lu and Yang (2011) examined the impact of safety climate on safety behavior in passenger ferry services. Their findings indicated that safety training and emergency preparedness were positively associated with safety behavior, including safety compliance and safety participation.

Despite safety climate is a critical element of safety behavior, this research proposes that the quality of leader-member exchange (LMX) may influence safety climate and port workers’ safety organizational citizenship behaviors (SOCB). Notably, studies of antecedents to safety behaviors have focused on either the quality of LMX (Hofmann and Morgeson, 1999; Hofmann et al., 2003; Hofmann and Stetzer, 1996) or organization factors (Griffin and Neal, 2000; Hofmann and Stetzer, 1996; Lu and Yang, 2011; Lu and Tsai, 2010; Zohar, 2002). The notion of LMX refers to a leader who develops different types of exchange relationships with their subordinates and that the quality of these relationships influences the attitudes and behaviors of the leader and member (Illies et al., 2007). The LMX theory is drawn from the social exchange theory (Blau, 1964) to explain a long-term and perceived mutual obligation on the part of employees to reciprocate high-quality relationship (Blau, 1964; Illies et al., 2007). A leader initiates social exchanges by bestowing favorable treatment upon a member who will be in turn obliged to work harder to benefit the leader as a means of reciprocation (Liden et al., 1997; Rockstuhl et al., 2012). In a work team, there are two exchange relationships among individuals and between leaders and members (Liao et al., 2010). LMX can be explained as the reciprocal exchanges between a leader and a member built on obligations, respect and trust (Grean and Uhl-Bien, 1995), whereas a team member exchange (TMX) refers to a member’s social exchanges with another team member based on the reciprocal feedback, assistance and contribution of ideas (Liao et al., 2010; Seers, 1989). Despite a number of studies showing that high-quality LMX relationships can enhance employees’ organizational citizenship behaviors (Hofmann et al., 2003; Wang et al., 2005; Illies et al., 2007), relative little researches has considered LMX and safety climate.
simultaneously influencing workers’ SOCB because these two exchange relationships co-existing within an organization.

Previous studies have found a positive influence of LMX on organizational citizenship behavior (Wang et al., 2005; Grean and Uhl-Bien, 1995; Illies et al., 2007). Safety climate could play a mediating role on the relationships between LMX and SOCB (Hofmann et al., 2003). Safety climate refers to the coherent set of expectations and perceptions that employees have regarding safety in their organization (Zohar, 1980). The values and norms of an organization might affect the behaviors of employees within the relationship of LMX. Nevertheless, it seems that a limited number of prior studies have examined the relationships between LMX, safety climate and employees’ SOCB. Therefore, this research drawn upon the social exchange theory and LMX theory to highlight the theoretical mechanism linking difference in organizational safety climate with employees’ SOCB. This research will specifically focus on the investigation of employees who are working in container terminal companies. A safe operation should be cooperated with closer social exchange relationships between supervisors and employees. To address the research objectives, the following key research questions are posited:

\( RQ1 \). How do the quality and differentiation of LMX affect employees’ SOCB in container terminal operations?

\( RQ2 \). How does safety climate influence container terminal operators’ SOCB?

\( RQ3 \). What are the mechanisms through safety climate to explain the variation in the quality of LMX and employees’ SOCB in container terminal operations?

Owing to its crucial importance for a long-term safety environment, the objective of this research is to examine the influence of LMX and safety climate on employees’ SOCB and the mediating effect of safety climate on the relationships between LMX and employees’ SOCB in the context of container terminal operations. Following this introductory section, the next section presents the theoretical background and research hypotheses on the relationships between LMX, safety climate and SOCB. An explanation of the methodology used to implement the research objective is described in Section 3. The results obtained from a questionnaire survey of employees’ perceptions are detailed in Section 4. Conclusions drawn from the research findings, practical implications are discussed in the final section.

This research contributes to the application of LMX on safety research in container terminal operations. This research provides a useful implication for container terminal operators to enhance LMX qualities and employees’ safety behavior through organizational participation, employee helping behaviors and informing workers to obey safety rule and regulation.

2. Theoretical background and research hypotheses

2.1 Leader-member exchange, safety climate and safety organizational citizenship behavior

According to the theory of social exchange, LMX relationships are characterized by a perceived obligation on the part of members to reciprocate high-quality relationships (Hofmann et al., 2003). High-quality relationships or exchanges built on high levels of interaction, trust, support and rewards that extend beyond what is specified in the normal job description (Dienecsh and Liden, 1986; Liden et al., 1997). Essentially, employees in a high quality of LMX relationship will feedback to their leaders or supervisors by participating in citizenship behaviors that benefit the leader and other colleagues within an organization (Liden et al., 1997). Hence, a high quality of social relationship will foster the set of citizenship behaviors.
Container terminal operation is one of the most risky industries. The main operators or workers in a container terminal include front-line stevedores, tallies, crane operators, tractor drivers, engineers and maintenance personnel. The yard supervisor is responsible for the terminal operations and protection of the safety of containers and workers. Therefore, team work must be importantly emphasized to ensure safety. People work in container terminals by participating in different roles with other members or co-workers within an organization. Although container terminal operators engaging in different specific works, both communications emphasized an interaction between the supervisor and worker is important to influence the behaviors of workers. Focal workers or members will be more likely to meet the expectations of the supervisor (leader) when focal members felt liking, respect and admiration for the supervisor. Thus, in a high-quality relationship, the terminal supervisor (leader) and worker participate in cooperative problem-solving, mainly resulting in a set of team work behaviors that are mutually enhanced. Conversely, in a low quality relationship, this team work will be failed to develop in container terminal operations and negatively influence safety.

Accordingly, terminal employees having high-quality relationships will value their work environment. Because safety is important concern in a high-risk environment, employees who value their behaviors would be doing their work safely. Therefore, a high quality of LMX relationship will cause terminal workers to increase their roles beyond what is formally required and participate in fostering SOCB in container terminal operations. SOCB is one kind of organizational citizenship behaviors which are specifically emphasized on enhancing the safety performance of the organization. Thus, this research posits the hypothesis:

\[ H1. \] LMX positively relates to safety climate in container terminal operations.

\[ H2. \] LMX positively relates to SOCB in container terminal operations.

2.2 Safety climate and safety organizational citizenship behavior

Organizational climate refers to shared perceptions of employees regarding the organizational policies, practices, procedures and employee behaviors that are rewarded and encouraged in a specific organization (Zohar and Tenne-Gazit, 2008). Organizational policies and practices relate to specific performance facets including financial performance, service quality and safety (Zohar and Tenne-Gazit, 2008). Safety climate is a specific form of organizational climate and is referred to individual perceptions of the safety value in the work environment (Neal et al., 2000). Safety climate refers to the coherent set of perceptions and expectations that employees regard safety in their organizations (Zohar, 1980). Safety climate can be defined as individual perceptions of safety-related practices, procedures and policies pertaining to safety issues that affect personal benefits at work (Christina et al., 2009; James and James, 1989). When these safety perceptions are shared and emphasized among individuals in a specific work environment, a safety climate emerges (Christina et al., 2009). Clarke (2006) used a meta-analysis to propose that safety climate is a meaningful determinant of safety behaviors and is related to accidents. Thus, safety climate is expected to positively influence employee’s safety behaviors and to reduce potential risks and accidents. A majority of prior studies (Brown and Holmes, 1986; Dedobbeleer and Beland, 1991; DeJoy, 1994; Gillen et al., 2002; Glendon and Litherland, 2001; Lu and Tsai, 2010; Lu and Yang, 2011; Zohar, 1980) suggest safety climate positively influence on safety performance. Lu and Yang (2011) demonstrated five dimensions of safety climate based on previous studies, namely, safety motivation (Griffin and Neal, 2000; Zohar, 1980), safety
policy (Lu and Tsai, 2008), safety communication (Clarke, 1999; Zohar, 2002), emergency preparedness (Lu, and Yang, 2011) and safety training (Zohar, 1980). Safety training and emergency preparedness which provided by an organization positively affect self-reported safety behaviors, such as safety compliance and safety participation. Accordingly, this research posits the hypothesis:

\[ H3. \] Safety climate positively relates to SOCB in container terminal operations.

3. Methodology

3.1 Sample
Data collection of this research was based on a questionnaire survey. The samples include employees who are working in Taiwanese container terminals and engage in operations, such as tally, lashing and stevedore activities. Questionnaires were delivered to 424 container terminal employees by research assistants in March 2016. A total of 265 usable questionnaires were collected, which represented 62.5 per cent of the target sample. Table I indicates that the majority of participants (51.7 per cent) were aged between 31 and 50 years, followed by aged between 51-60 years (22.6 per cent), aged less than 30 years (17.7 per cent) and aged more than 60 years (8.0 per cent). Nearly 18 per cent were aged 30 or below and 8 per cent were aged 60 or above. In total, 19 per cent of the participants were supervisors or at a higher position and 24.2 per cent and 48.2 per cent were shore workers and yard workers, respectively. Only 8.3 per cent of the respondents were maintenance engineers. Results indicated that more than 67 per cent of the respondents had attained a bachelor’s degree or above educational level. Nearly 33 per cent of the respondents had attained a senior high school or below educational level. The main job nature of more than half of the

<table>
<thead>
<tr>
<th>Characteristics of the respondents</th>
<th>Frequency</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Age</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Less than 30</td>
<td>47</td>
<td>17.7</td>
</tr>
<tr>
<td>31-40</td>
<td>68</td>
<td>25.7</td>
</tr>
<tr>
<td>41-50</td>
<td>69</td>
<td>26.0</td>
</tr>
<tr>
<td>51-60</td>
<td>60</td>
<td>22.6</td>
</tr>
<tr>
<td>More than 60</td>
<td>21</td>
<td>8.0</td>
</tr>
<tr>
<td><strong>Job title</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Supervisor or above</td>
<td>51</td>
<td>19.3</td>
</tr>
<tr>
<td>Shore worker</td>
<td>64</td>
<td>24.2</td>
</tr>
<tr>
<td>Maintenance engineer</td>
<td>22</td>
<td>8.3</td>
</tr>
<tr>
<td>Yard worker</td>
<td>128</td>
<td>48.2</td>
</tr>
<tr>
<td><strong>Educational level</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Senior high school or below</td>
<td>97</td>
<td>32.8</td>
</tr>
<tr>
<td>Bachelor’s degree</td>
<td>161</td>
<td>60.8</td>
</tr>
<tr>
<td>Master’s degree or above</td>
<td>17</td>
<td>6.4</td>
</tr>
<tr>
<td><strong>Department</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Warehousing</td>
<td>55</td>
<td>20.8</td>
</tr>
<tr>
<td>Container operations</td>
<td>112</td>
<td>53.0</td>
</tr>
<tr>
<td>Maintenance</td>
<td>25</td>
<td>9.4</td>
</tr>
<tr>
<td>Engineering</td>
<td>15</td>
<td>5.7</td>
</tr>
<tr>
<td>Other</td>
<td>56</td>
<td>21.1</td>
</tr>
</tbody>
</table>

Table I. Profile of the respondents (n = 265)
respondents was in container operations, followed by others (21.1 per cent), warehousing (20.8 per cent), maintenance (9.4 per cent) and engineering (5.7 per cent).

3.2 Measure

3.2.1 Leader-member exchange. This research was interested in the overall exchange relationship. Participants were asked to rate the LMX relationship with their supervisor by using 11 measures as recommended by Li and Liao (2014), Maslyn and Uhl-Bien (2001) and Vidyarthiv et al. (2014). A five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree) was used such that higher scores reflected higher quality LMX. Reliability test based on a Cronbach’s alpha was 0.85.

3.2.2 Safety climate. Safety climate was measured by using a revised and updated version from previous studies of Glendon and Litherland (2001), Neal et al. (2000), Lu and Yang (2011), Probst (2015) and Zohar (1980). Similarly, 18 items used a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree) with higher scores representing higher safety climates. In particular, 18 safety climate items can be categorized into three dimensions, namely, supervisory safety, safety training and safety response. Reliability test based on a Cronbach’s alpha for supervisory safety, safety training and safety response were 0.95, 0.89 and 0.87, respectively.

3.2.3 Safety organizational citizenship behavior. SOCB was measured by modifying several OCB measures. Drawing on the theoretical and prior studies by Farh et al. (2004), Lee et al. (2007) and Podsakoff et al. (2003), SOCB was measured by 16 items using a five-point Likert scale where 1 corresponding to “strongly disagree” and 5 representing “strongly agree” and are intended to capture SOCBs demonstrated by container terminal employees. These SOCB items can be identified as three dimensions, namely, safety-related participation, helping and courtesy. Scale scores were created such that higher scores reflected higher performance of the safety behavior. Reliability test based on a Cronbach’s alpha for organizational participation, helping and courtesy were 0.92, 0.72 and 0.89, respectively.

3.3 Analytical method

We used the IBM SPSS 24.0 (2016) for Windows and AMOS 24.0 (2016) statistical packages for the following analyses. Regarding the research steps and methods, a descriptive statistic and a confirmatory factor analysis (CFA) were used to examine unidimensionality and convergent validity. Moreover, a structural equation modeling was used to examine the effects of SOCB and safety climate on safety behavior, as well as the effect of safety climate on SOCB. Several analytical methods were conducted in this study, including the descriptive statistics of respondents’ profiles and measures, exploratory studies of the dimensions of LMX, safety climate and SOCB, as well as casual research of the relationships between variables. The latter refers to a cause-and-effect relationship that was used to examine the influence of LMX and safety climate on employee SOCB and the mediating effect of safety climate. First, a widely review of previous studies and interviews with terminal operators were conducted. Measures for LMX, safety climate and SOCB were drawn from previous studies. To increase the adequacy of measures and validate the research hypotheses, this research conducted in-depth interviews and discussions with 10 practitioners in container terminal. Second, an exploratory factor analysis (EFA) and CFA were used to validate the relationships between latent variables (i.e. LMX, safety climate and SOCB) and manifest variables (i.e. measure items) and verify measurement models. A CFA with multiple-indicator measurement was adopted to evaluate unidimensionality between variables (Segar, 1997).
Third, a structural equation modeling (SEM) was adopted to test the research hypotheses and assess the relationships among the latent variables and manifest variables. To validate the measures and the fit of the conceptual model, unidimensionality, item reliability and discriminate validity were examined in this research (Iacobucci and Churchill, 2010).

Because the data collection of this research was based on a self-report questionnaire survey, the responses may be biased as the result of measuring multiple constructs using a single respondent. It is possible to have the common method variance (CMV) problem (Podsakoff et al., 2003). According to the suggestion from Podsakoff et al. (2003), this research used the ex-ante approach to reduce the potential CMV bias. First, we informed the participants that their responses will be confidential and anonymous. The respondents were notified that there were no right or wrong answers to encourage them to answer as honestly as possible. Second, the dependent variable (i.e. SOCB) was measured based on employees’ perceptions of their SOCB, while the independent variables (LMX and safety climate) were based on employees’ perceptions of their social exchange relationships with their supervisors working in the same team. As a result, the problem of common method variance problem can be reduced in this research.

4. Results
4.1 Exploratory factor analysis results
This research uses an exploratory factor analysis to identify the major factors/dimensions underlying the measurement items of the safety climate and SOCB in the context of container terminal companies. Principal component analysis with VARIMAX rotation was used to obtain the factors with eigenvalues greater than 1.0 (Hair et al., 2010).

Exploratory factor analysis with VARIMAX rotation was used to clarify the factors underlying SOCB. The Kaiser-Meyer-Olkin value was 0.928 and Bartlett’s Test of Sphericity was 2469 \((p < 0.000)\), indicating that the results were accepted. Only one factor was obtained to underlie the LMX dimension was viewed by the survey respondents. The single factor consisted of all items, namely, “I like my supervisor very much as a person, my supervisor is the kind of person one would like to have as a friend, my supervisor is a lot of fun to work with, my supervisor would defend me to others in the organization if I made an honest mistake, my supervisor would come to my defense if I was attacked by others, my supervisor defends my work actions to a superior, even without complete knowledge of the issue in question, I do work for my supervisor that goes beyond what is specified in my job description, I am willing to apply extra efforts, beyond those normally required, to further the interests of my work group, I respect my supervisor’s knowledge of and competence on the job, I admire my supervisor’s professional skills and I am impressed with my supervisor’s knowledge of his/her job. Therefore, this factor was identified as a LMX dimension. “My supervisor defends my work actions to a superior, even without complete knowledge of the issue in question” had the highest factor loading on this dimension. This factor accounted for 64.7 per cent of the total variance.

Table II shows three factors underlay the 18 measuring safety climate attributes. The KMO statistics was 0.952 and Bartlett’s Test of Sphericity was 3,682 \((p < 0.001)\), which confirmed their suitability for further factor analysis (Hair et al., 2010). The three factors accounted for approximately 71.7 per cent of the total variance. These three factors/dimensions of safety climate are described below.

Factor 1 was designated the supervisory safety, as it consisted of the following eight items:

1. my supervisors involve in setting safety goals with employee;
2. my supervisors care about employee’s safety;
(3) my supervisors discuss regular safety issues with employees;
(4) my supervisors enforce safety rules;
(5) my supervisors praise employees’ employees’ safety behaviors;
(6) my supervisors audits employees’ safe behaviors;
(7) my supervisors mention safety to be as equally important as the efficiency; and
(8) my supervisors act on safety suggestions from employees.

As these items were related to the supervisor, this factor was therefore identified as supervisory safety. “My supervisors involve in setting safety goals with employees” had the highest loading on this dimension. This factor accounted for 55.1 per cent of the total variance.

Factor 2 was labelled the safety training factor, as it comprised the following five items:

(1) safety training programs do apply to my workplace;
(2) the design of safety training program is good;
(3) safety training programs are helpful to prevent accidents;
(4) safety training programs in my company do work; and
(5) safety training programs in my company are enough.

“Safety training programs do apply to my workplace” had the highest factor loading on this factor, followed by *the design of safety training program is good*. Factor 2 accounted for 10.1 per cent of the total variance.

Factor 3 was called the safety response factor, as it comprised the following five items:

(1) my company responds quickly to safety concerns;
(2) my company investigates safety problems quickly;

Table II.
Exploratory factor analysis of safety climate attributes

<table>
<thead>
<tr>
<th>Safety climate attributes</th>
<th>F1</th>
<th>F2</th>
<th>F3</th>
</tr>
</thead>
<tbody>
<tr>
<td>SUP1: My supervisors involve in setting safety goals with employees</td>
<td>0.841</td>
<td>0.251</td>
<td>0.179</td>
</tr>
<tr>
<td>SUP2: My supervisors care about employee’s safety</td>
<td>0.833</td>
<td>0.210</td>
<td>0.219</td>
</tr>
<tr>
<td>SUP3: My supervisors discuss regular safety issues with employees</td>
<td>0.826</td>
<td>0.261</td>
<td>0.212</td>
</tr>
<tr>
<td>SUP4: My supervisors enforce safety rules</td>
<td>0.809</td>
<td>0.216</td>
<td>0.275</td>
</tr>
<tr>
<td>SUP5: My supervisors praise employees’ employees’ safety behaviors</td>
<td>0.792</td>
<td>0.263</td>
<td>0.192</td>
</tr>
<tr>
<td>SUP6: My supervisors audits employees’ safe behaviors</td>
<td>0.777</td>
<td>0.242</td>
<td>0.221</td>
</tr>
<tr>
<td>SUP7: My supervisors mention safety to be as equally important as the efficiency</td>
<td>0.742</td>
<td>0.310</td>
<td>0.259</td>
</tr>
<tr>
<td>SUP8: My supervisors act on safety suggestions from employee</td>
<td>0.720</td>
<td>0.279</td>
<td>0.311</td>
</tr>
<tr>
<td>TRA1: Safety training programs do apply to my workplace</td>
<td>0.238</td>
<td>0.778</td>
<td>0.296</td>
</tr>
<tr>
<td>TRA2: The design of safety training program is good</td>
<td>0.296</td>
<td>0.753</td>
<td>0.192</td>
</tr>
<tr>
<td>TRA3: Safety training programs are helpful to prevent accidents</td>
<td>0.236</td>
<td>0.734</td>
<td>0.325</td>
</tr>
<tr>
<td>TRA4: Safety training programs in my company do work</td>
<td>0.349</td>
<td>0.721</td>
<td>0.316</td>
</tr>
<tr>
<td>TRA5: Safety training programs in my company are enough</td>
<td>0.341</td>
<td>0.718</td>
<td>0.224</td>
</tr>
<tr>
<td>RES1: My company responds quickly to safety concerns</td>
<td>0.327</td>
<td>0.140</td>
<td>0.781</td>
</tr>
<tr>
<td>RES2: My company investigates safety problems quickly</td>
<td>0.256</td>
<td>0.220</td>
<td>0.776</td>
</tr>
<tr>
<td>RES3: My company posts warning sign for hazardous cargo</td>
<td>0.124</td>
<td>0.276</td>
<td>0.708</td>
</tr>
<tr>
<td>RES4: My company provides safety information</td>
<td>0.261</td>
<td>0.308</td>
<td>0.705</td>
</tr>
<tr>
<td>RES5: My company frequently conducts safety inspections</td>
<td>0.248</td>
<td>0.299</td>
<td>0.606</td>
</tr>
</tbody>
</table>

Eigenvalues       9.92  1.82  1.17  
Percentage variance 55.1  10.1  6.5  
Cronbach’s alpha   0.95  0.89  0.87
(3) my company posts warning sign for hazardous cargo;
(4) my company provides safety information; and
(5) my company frequently conducts safety inspections.

The item my company responds quickly to safety concerns had the highest factor loading on this factor, followed by my company investigates safety problems quickly. Factor 3 accounted for 6.5 per cent of the total variance.

Factor analysis was also used to identify SOCB attributes. Results revealed that approximately 68.5 per cent of the total variance was represented by the information contained in the factor matrix as shown in Table III. Three SOCB dimensions were found to underlie the various sets of safety organizational citizenship behavior attributes of container terminal operations. They were identified and described below.

Factor 1 was called the organizational participation factor. It consisted of the following seven items:

(1) attending safety meetings;
(2) volunteering for safety committees;
(3) participating in setting safety goals;
(4) making safety-related recommendations about work activities;
(5) encouraging co-workers to get involved in safety issues;
(6) raising safety concerns during planning sessions; and
(7) expressing opinions on safety matters even if others disagree.

These items represent attributes that are by nature with organizational participation. “Attending safety meetings” had the highest factor loading on this factor, followed by volunteering for safety committees and participating in setting safety goals. Factor 1 accounted for 52.6 per cent of the total variance.

<table>
<thead>
<tr>
<th>SOCB attributes</th>
<th>OCB 1</th>
<th>OCB 2</th>
<th>OCB 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>PAR1: Attending safety meetings</td>
<td>0.769</td>
<td>0.106</td>
<td>0.263</td>
</tr>
<tr>
<td>PAR2: Volunteering for safety committees</td>
<td>0.761</td>
<td>0.203</td>
<td>0.197</td>
</tr>
<tr>
<td>PAR3: Participating in setting safety goals</td>
<td>0.743</td>
<td>0.055</td>
<td>0.291</td>
</tr>
<tr>
<td>PAR4: Making safety-related recommendations about work activities</td>
<td>0.710</td>
<td>0.267</td>
<td>0.195</td>
</tr>
<tr>
<td>PAR5: Encouraging co-workers to get involved in safety issues</td>
<td>0.680</td>
<td>0.164</td>
<td>0.342</td>
</tr>
<tr>
<td>PAR6: Rising safety concerns during planning sessions</td>
<td>0.610</td>
<td>0.373</td>
<td>0.207</td>
</tr>
<tr>
<td>PAR7: Expressing opinions on safety matters even if others disagree</td>
<td>0.599</td>
<td>0.499</td>
<td>0.082</td>
</tr>
<tr>
<td>HEL1: Helping teach safety procedures to new workers</td>
<td>0.092</td>
<td>0.858</td>
<td>0.247</td>
</tr>
<tr>
<td>HEL2: Helping others with safety-related responsibilities</td>
<td>0.160</td>
<td>0.799</td>
<td>0.381</td>
</tr>
<tr>
<td>HEL3: Helping other crew members learn about safe work practices</td>
<td>0.322</td>
<td>0.717</td>
<td>0.361</td>
</tr>
<tr>
<td>COU1: Passes along information to co-worker</td>
<td>0.377</td>
<td>0.684</td>
<td>0.290</td>
</tr>
<tr>
<td>COU2: Trying to prevent co-workers from being injured on the job</td>
<td>0.165</td>
<td>0.269</td>
<td>0.816</td>
</tr>
<tr>
<td>COU3: Informing co-workers to obey safety rule</td>
<td>0.319</td>
<td>0.305</td>
<td>0.757</td>
</tr>
<tr>
<td>COU4: Inspecting new co-workers to follow safety procedures</td>
<td>0.367</td>
<td>0.248</td>
<td>0.732</td>
</tr>
<tr>
<td>COU5: Taking action to stop safety violations to protect co-workers</td>
<td>0.327</td>
<td>0.289</td>
<td>0.704</td>
</tr>
<tr>
<td>COU6: Be aware of the safety of co-workers</td>
<td>0.313</td>
<td>0.438</td>
<td>0.561</td>
</tr>
</tbody>
</table>

Eigenvalues 8.42 1.55 1.00
Percentage variance 52.6 9.6 6.3
Cronbach’s alpha 0.92 0.72 0.89

Table III. Exploratory factor analysis of SOCB attributes
Factor 2 was designated the helping behavior factor. It comprised the following three items:

(1) helping teach safety procedures to new workers;
(2) helping others with safety-related responsibilities; and
(3) helping other crew members learn about safe work practices.

These items represent attributes that are by nature related to helping behavior. Factor 2 accounted for 9.6 per cent of the total variance. The item “helping teach safety procedures to new workers” had the highest factor loading on this factor, followed by helping others with safety-related responsibilities.

Factor 3 was called the courtesy factor. It included the following six items:

(1) passes along information to co-worker;
(2) trying to prevent co-workers from being injured on the job;
(3) informing co-workers to obey safety rule;
(4) inspecting new co-workers to follow safety procedures;
(5) taking action to stop safety violations to protect co-workers; and
(6) be aware of the safety of co-workers.

“Passes along information to co-worker” had the highest factor loading on this factor, followed by trying to prevent co-workers from being injured on the job. Factor 3 accounted for 6.3 per cent of the total variance.

4.2 Reliability and validity

A content validity was conducted through a theoretical review and pilot study. Measure in the questionnaire was based on previous studies and discussed with a number of practitioners in container terminals. Tables II and III show the Cronbach’s alpha values which were well above the 0.7 value considered adequate for achieving a satisfactory level of reliability in research (Churchill and Iacobucci, 2002). Table IV shows the means, standard deviations and corrected item-total correlation coefficients of each factor, which are all above the recommended threshold of 0.3 (Hair et al., 2010).

Table IV. Means, standard deviations and correlations between LMX, safety climate and SOCB

<table>
<thead>
<tr>
<th>Constructs</th>
<th>Mean</th>
<th>SD</th>
<th>LMX</th>
<th>SCL1</th>
<th>SCL2</th>
<th>SCL3</th>
<th>OCB1</th>
<th>OCB2</th>
<th>OCB3</th>
</tr>
</thead>
<tbody>
<tr>
<td>LMX</td>
<td>3.71</td>
<td>0.746</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SCL1</td>
<td>3.95</td>
<td>0.699</td>
<td>0.614**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SCL2</td>
<td>3.94</td>
<td>0.622</td>
<td>0.544**</td>
<td>0.662**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SCL3</td>
<td>4.17</td>
<td>0.575</td>
<td>0.473**</td>
<td>0.609**</td>
<td>0.662**</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>OCB1</td>
<td>3.92</td>
<td>0.529</td>
<td>0.384**</td>
<td>0.431**</td>
<td>0.496**</td>
<td>0.294**</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OCB2</td>
<td>4.17</td>
<td>0.534</td>
<td>0.426**</td>
<td>0.517**</td>
<td>0.538**</td>
<td>0.445**</td>
<td>0.712**</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>OCB3</td>
<td>4.14</td>
<td>0.596</td>
<td>0.355**</td>
<td>0.477**</td>
<td>0.471**</td>
<td>0.438**</td>
<td>0.564**</td>
<td>0.745**</td>
<td>1</td>
</tr>
</tbody>
</table>

Notes: SD: Standard deviation; **Significance level p < 0.01; LMX: Leader-member exchange; SCL1: Supervisory safety; SCL2: Safety training; SCL3: Safety response; OCB1: Organizational participation; OCB2: Helping behavior; OCB3: Courtesy
4.3 Confirmatory factor analysis results
CFA was performed to ensure the validity of the measurement model (Anderson and Gerbing, 1988) consisting of three constructs, namely, LMX, safety climate and SOCB. A number of goodness-of-fit indices recommended by previous researchers were examined to assess the fit and unidimensionality of the measurement model (Bagossib and Yi, 1988; Koufterosk, 1999). The statistical criteria for model modification decisions included standardized residuals and model fit indices. Principally, standardized residuals less than 2.5 or greater than 2.5 do not suggest a problem (Hair et al., 2010). However, standardized residual value of one item I like my supervisor very much as a person (LMX1) in the LMX dimension exceeded 2.5 and therefore, was removed from further analyses. The results show the following fit values: Chi-square statistic (\(\chi^2 = 210.5\) df = 84), the normal fit index (NFI = 0.94), comparative fit index (CFI = 0.96), goodness-of-fit index (GFI = 0.90), adjusted goodness-of-fit index (AGFI = 0.87), root mean square residual (RMR = 0.02) and root mean square error of approximation (RMSEA = 0.07). This indicates that the model was acceptable (Hair et al., 2010). Furthermore, a convergent validity was tested by indicating the critical ratio (CR) which indicated that all are statistically significant on the factor loadings (Dunn et al., 1994). Critical ratio represents the parameter estimated, divided by its standard error. The CR value should be greater than 1.96 or smaller than –1.96 for the estimate to be significant (Koufteros, 1999; Byrne, 2016; Hair et al., 2010). The results confirmed that all indicators measured the same construct and providing satisfactory evidence of the convergent validity and unidimensionality of each construct (Anderson and Gerbing, 1988).

4.4 Results of hypotheses testing
The results of hypotheses testing were shown in Figure 1. The results indicated that goodness-of-fit index was calculated to be 0.91 and the adjusted goodness-of-fit index yielded 0.87 after adjustment was made for degrees of freedom relative to the number of variables. This indicated that 91 per cent of the variances and covariances in the data observed were predicted by the estimated model. Moreover, results of fitting the structural model to the data revealed that the model had a good fit as indicated by the normed fit index (NFI = 0.93), root mean square residual (RMR = 0.02) and root-mean-square error of approximation (RMSEA = 0.07).

Table V summarizes the hypotheses testing results which indicated that all hypothesized relationships were significant and in the expected direction, except for the path from LMX to SOCB, which was shown to be insignificant. As shown in Figure 1, LMX was found to have a positive influence on safety climate (estimate = 0.43, C.R. = 10.2) and safety climate was positively related to SOCB (estimate = 0.65, C.R. = 6.3). Thus, \(H2\) and \(H3\) were supported. As regard, the relationship between LMX and SOCB, the results indicated that there was no direct impact of LMX on SOCB in this study. \(H1\) was therefore not supported. Nevertheless, the results suggested that LMX had an influence on safety climate and indirectly affected the SOCB in container terminal operations.

Hair et al. (2010) suggested that a mediating effect existed if the relationship between independent and dependent variables was reduced in magnitude and became insignificant. Accordingly, further analysis was conducted to examine whether safety climate played an intermediary role between LMX and SOCB. The findings imply that employees with a higher perception of LMX will have higher safety climate and better SOCB. These are consistent with the findings reported in previous studies (Brown and Holmes, 1986; Dedobbeleer and Beland, 1991; Dejoy, 1994; Gillen et al., 2002; Glendon and Litherland, 2001; Lu and Tsai, 2010; Lu and Yang, 2011).
Further analysis was conducted to examine the effect of the mediating variable (safety climate) on the relationship between LMX and SOCB. Following Hair et al.'s (2010) suggestion, a fully mediating effect exists if the relationship between independent variable (LMX) and dependent variable (SOCB) is not significant. As shown in Figure 2, this research specified a direct path between LMX and SOCB. The model provided an acceptable fit with the data ($\chi^2$/df = 2.81, $p < 0.01$, GFI = 0.907, AGFI = 0.868, CFI = 0.961, IIF = 0.961, NFI = 0.927, RFI = 0.922, RMR = 0.021, RMSEA = 0.08). It was noted that there was a significant and positive effect of LMX on SOCB (estimate = 0.36) in the model. Figure 2 showed that safety climate mediated the relationship between LMX and SOCB (James et al., 2006; Mayer et al., 2010).

As shown in Figure 1 and Table VI, the research findings revealed that LMX did not have a direct effect on SOCB. However, the results indicated that LMX had a positive direct effect on safety climate (direct effect = 0.43), whereas safety climate had a direct positive effect on SOCB (direct effect = 0.65). Therefore, LMX had an indirect effect on SOCB.

Notes: LMX1: I like my supervisor very much as a person; LMX2: My supervisor is the kind of person one would like to have as a friend; LMX3: My supervisor is a lot of fun to work with; LMX4: My supervisor would defend me to others in the organization if I made an honest mistake; LMX 5: My supervisor would come to my defense if I was attacked by others; LMX 6: My supervisor defends my work actions to a superior, even without complete knowledge of the issue in question; LMX 7: I do work for my supervisor that goes beyond what is specified in my job description; LMX 8: I am willing to apply extra efforts, beyond those normally required, to further the interests of my work group; LMX 9: I respect my supervisor’s knowledge of and competence on the job; LMX 10: I admire my supervisor’s professional skills; and LMX 11: I am impressed with my supervisor’s knowledge of his/her job.
Table V. Structural equation modeling results

<table>
<thead>
<tr>
<th>Path</th>
<th>Estimate</th>
<th>S.E.</th>
<th>C.R.</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCL → LMX</td>
<td>0.435</td>
<td>0.043</td>
<td>10.219</td>
<td>**</td>
</tr>
<tr>
<td>SOCB → LMX</td>
<td>-0.018</td>
<td>0.050</td>
<td>-0.367</td>
<td>0.714</td>
</tr>
<tr>
<td>SOCB → SCL</td>
<td>0.650</td>
<td>0.103</td>
<td>6.308</td>
<td>**</td>
</tr>
<tr>
<td>LMX11 → LMX</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LMX10 → LMX</td>
<td>0.977</td>
<td>0.046</td>
<td>21.098</td>
<td>**</td>
</tr>
<tr>
<td>LMX9 → LMX</td>
<td>0.912</td>
<td>0.058</td>
<td>15.647</td>
<td>**</td>
</tr>
<tr>
<td>LMX8 → LMX</td>
<td>0.899</td>
<td>0.063</td>
<td>14.337</td>
<td>**</td>
</tr>
<tr>
<td>LMX6 → LMX</td>
<td>1.148</td>
<td>0.067</td>
<td>17.145</td>
<td>**</td>
</tr>
<tr>
<td>LMX5 → LMX</td>
<td>1.114</td>
<td>0.067</td>
<td>16.528</td>
<td>**</td>
</tr>
<tr>
<td>LMX4 → LMX</td>
<td>1.065</td>
<td>0.067</td>
<td>16.010</td>
<td>**</td>
</tr>
<tr>
<td>LMX3 → LMX</td>
<td>0.979</td>
<td>0.060</td>
<td>16.457</td>
<td>**</td>
</tr>
<tr>
<td>LMX2 → LMX</td>
<td>1.071</td>
<td>0.064</td>
<td>16.657</td>
<td>**</td>
</tr>
<tr>
<td>Response → SCL</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Training → SCL</td>
<td>1.203</td>
<td>0.090</td>
<td>13.310</td>
<td>**</td>
</tr>
<tr>
<td>Supervisor → SCL</td>
<td>1.340</td>
<td>0.105</td>
<td>12.706</td>
<td>**</td>
</tr>
<tr>
<td>Participation ← SOCB</td>
<td>1.000</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Courtesy ← SOCB</td>
<td>1.288</td>
<td>0.085</td>
<td>14.845</td>
<td>**</td>
</tr>
<tr>
<td>Helping ← SOCB</td>
<td>1.178</td>
<td>0.091</td>
<td>12.999</td>
<td>**</td>
</tr>
</tbody>
</table>

Notes: S.E. is an estimate of the standard error of the covariance; C.R. is obtained by dividing the covariance estimate by its standard error; and **significance level p < 0.01

Table VI. Path analysis results

<table>
<thead>
<tr>
<th>Path</th>
<th>Total effect</th>
<th>Direct effect</th>
<th>Indirect effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>LMX → Safety climate</td>
<td>0.43</td>
<td>0.43</td>
<td>–</td>
</tr>
<tr>
<td>LMX → SOCB</td>
<td>0.28</td>
<td>–</td>
<td>0.28</td>
</tr>
<tr>
<td>Safety climate → SOCB</td>
<td>0.65</td>
<td>0.65</td>
<td>–</td>
</tr>
</tbody>
</table>

Notes: Chi sq/df = 2.814, P-Value = 0.000, GFI = 0.921, AFGI = 0.877, CFI = 0.966, IFI = 0.967, NFI = 0.949, RFI = 0.933, RMR = 0.021, RMSEA = 0.083

Figure 2. Direct path between LMX and SOCB
MABR
2,4

(indirect effect = 0.28) via safety climate. The total effect between LMX and SOCB was 0.28, providing evidence of safety climate’s mediating effect.

5. Discussion and conclusions
Given the prevalence of accidents and unsafe behavior in container terminal operations, this research sought to examine the relationships among LMX, safety climate and employees’ SOCB in the container terminal context. Theoretically, this study highlights the importance of LMX and safety climate in explaining the SOCB of employees. Moreover, the study answers several important questions: how LMX and safety climate influence employees’ SOCB in container terminal operations. In particular, this study revealed the mediating effect of safety climate on the relationship between LMX and employees’ SOCB.

To the best of the author’s knowledge, this is the first study to provide empirical evidence of the importance of LMX and safety climate in explaining employees’ SOCB in the container terminal context. More specifically, this study fills the gap in the maritime and transportation literatures, as there is a scarcity of studies explaining employee safety behavior from LMX and safety climate perspectives in the container terminal or port context.

This research makes several important contributions to the field of maritime safety in three ways. First, given the timely need for maritime safety researchers to adopt LMX in examining safety behavioral-related problems. Second, as there seems to be a lack of LMX applications in the maritime safety literature to date, this research provides safety researchers with a comprehensive methodology to follow when they apply LMX in their researches. Finally, this research contributes to the body of maritime safety literature with findings on LMX adoption in the container terminal context.

5.1 Implications of the study findings
This study has several implications for safety research and LMX. First, this research highlights the importance of LMX and SOCB on safety and maritime studies. Although previous studies on safety climate (Lu and Tsai, 2010; Lu and Yang, 2011; Zohar, 1980) noted that an organization’s values or norms of safety could influence employees’ SOCB, relative little research to date has examined the influence of LMX relationship. The research findings add to the emerging body of safety research, suggesting that front-line supervisor, and the climates they help to create within their work groups can have a positive impact on the SOCM of their subordinates in container terminal operations.

Second, study findings demonstrate the value of LMX, as LMX has been found to be positively associated with safety climate. This study suggests that container terminal operators can focus on developing a safety climate that emphasizes the good SOCB of employees by focusing on adherence to the law and professional standards and public rather than self-interest. To increase safe conduct, an organization should develop a closer LMX relationship to encourage safety climate and systems that reward team work of SOCB and discipline unsafe conduct.

Third, this research found that safety climate plans an important role in influencing employees’ SOCB that must be taken into consideration by terminal operators. Consistent with previous studies (Lu and Tsai, 2010; Lu and Yang, 2011; Zohar, 1980), safety climate was found to be positively related to employees’ SOCB. Given the benefits of safety climate in increasing employees’ SOCB, container terminal operators should endeavor to select and/or train safety programmes for employees and supervisors. Training programs should include communicating the importance of safety, rewarding and supporting employees who behave safely and serve as SOCB role models. Container terminal operators should develop a safety response system to create a safety climate.
This research has not found the direct effect of LMX on SOCB. Instead, this study has found the mediating effect of safety climate on the relationship between LMX and SOCB. Another important finding of this study is that safety climate mediates the relationship between LMX and employee SOCB. Therefore, terminal operators could enhance LMX qualifying through organizational participation, employee helping behaviors and informing workers to obey safety rule and regulation. When employees operate in a safety climate, they are likely to engage in SOCB.

5.2 Limitations and future research

This research has several potential limitations to provide meaningful directions for future research. First, the collected data on SOCB and perceptions of safety climate and LMX relationship in container terminal operations may have been subject to bias as a result of the reluctance of the respondents to report unsafe behaviors because of potential personal repercussions and an interest in avoiding lawsuits against the organization. Second, this study was limited to LMX dimensions adapted from the studies of Li and Liao (2014) and Vidyarthi et al. (2014). Future research could examine the linkages between LMX, ethical climate, safety performance and supervisor leadership influence (Wimbush and Shepard, 1994). Third, it would be valuable to study the differences in SOCB at the individual level (e.g. educational level, age and religion) using safety culture as a sociological, group-based construct (Treviño et al., 1998). Fourth, this research focused specifically on employees from the container terminal operators in Taiwan. It would be valuable to collect data from employees from other countries to obtain a balanced view of the relationship between LMX, team-member exchange (TMX) (Hofmann et al., 2003; Liden et al., 1997), safety climate and employee SOCB in container terminal operations. Finally, future studies may also be conducted using the longitudinal analysis to examine the effects of safety climate and LMX on SOCB in other industries such as shipping or port operations.

References


Further reading


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Cold supply chain of longline tuna
and transport choice

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National Kaohsiung University of Science and Technology, Kaohsiung, Taiwan, and

Han-Yu Lin
Taiwan Tuna Association, Kaohsiung, Taiwan

Abstract
Purpose – The four purposes of this study are to understand the development and the current status of Taiwan’s far seas longline tuna fisheries through a review of the literature and interviews; to investigate the attitude of Taiwanese fishing vessel operators fishing in the Indian Ocean concerning the use of transportation under the influence of various factors; to analyze the relationship between changes in the transportation behavior of Taiwanese fishing vessel operators and various factors; and to provide suggestions to government and industry associations concerning the development of viable response strategies.

Design/methodology/approach – This paper uses methods including factor analysis and the analytic hierarchy process to analyze questionnaires collected from industry personnel and governmental personnel involved in the supply chain system of the longline tuna fishery in the Indian Ocean.

Findings – It is found that 16 assessment criteria in four major dimensions have major influence on the choice of cold chain transport. An assessment of all dimensions indicates that reefer ships are still the preferred means of transshipping frozen catch.

Originality/value – This paper seeks to investigate factors affecting choice of cold chain mode of transport from the perspective of Taiwanese companies operating longline tuna fishing vessels in the Indian Ocean, which are chiefly motivated by the need to reduce operating costs, and also looks at their choices of means of transport.

Keywords AHP, Cold chain, Longline tuna, Modal choice

Paper type Research paper

1. Introduction
Fishing is an important primary industry contributing to economic development in many countries, and its importance spans the aspects of economic production, diplomacy, trade, employment, and its role as the main source animal protein for human beings. As a result, fish and fishery products account for the highest proportion of foods in global trade (FAO, 2010). Tuna and tuna-like species have high economic value, and their main markets include sashimi, steaks and canned tuna. Japan is the world’s most important consumer of sashimi. According to the 2010 statistics of the United Nations Food and Agriculture Organization (FAO), the six leading tuna fishing countries are Japan, Taiwan, South Korea, France, Spain and China. Following Japan, Taiwan is the second important tuna fishing country in the world (Haward and Bergin, 2000).

Among the far seas fisheries in Taiwan, the longline tuna industry occupies a very significant position with its large scale of operations and highest output value. According to
the Taiwan Fisheries Statistical Yearbook 2011, the average output and value of the longline tuna industry had exceeded 217,000 MT and NT$28.3bn during the previous three years, and these figures represented around 33 per cent of the total far seas fishing output and 65 per cent of the total far seas fishing value in Taiwan (Taiwan Fisheries Agency, 2016). This fishery can be classified as the conventional longline tuna and the super freezer longline tuna fisheries based on the target species and the freezing facilities. The target species of the conventional longline tuna fishery is albacore, which is chiefly supplied to American-owned canneries as the raw material in canned tuna or exported to Europe for use in fish fillets. The refrigeration equipment of the conventional longline tuna vessels can freeze fishes to a temperature of −35°C. In the super freezer tuna fishery, the refrigeration equipment of vessels has a freezing capacity of −50 to −60°C and the fishery’s catch is mostly sold to Japan for the sashimi market.

After Taiwanese longline tuna fishing vessels have operated in the Indian Ocean for a certain period of time, they will choose to transship their frozen fishes at sea or in port in accordance with the plans of the company. It can be seen from the statistics in Figure 1 that operators have remained heavily dependent on freezer carrier vessels over recent years, and the number of transshipments increased briefly from 690 in 2008 to 564 in 2016. However, in view of high fuel prices, international regulations, the threat of piracy and other factors, some fishing vessels operating in the Indian Ocean have returned to Kaohsiung, Taiwan, and subsequently shifted to fishing in the Pacific or Atlantic Ocean. From 2010 to 2016, some operators have preferred to transship their catches to reefer container ships in port.

Figure 2 shows that 75 per cent of the reefer container ships used by the longline tuna industry were operated by MAERSK from 2008 to 2016, followed by 11 per cent operated by CMA CGM and 4 per cent operated by APL. The chief reason for this is that only MAERSK and CMA CGM shipping companies have reefer containers of −60°C, −40°C, −35°C and −25°C, and other companies have not any −60°C container with the same capacity. This reason has allowed MAERSK and CMA CGM can monopolize the reefer container market. On the other hand, operators have found that the quality of MAERSK’s service has happened to such problems as uneven quality of refrigeration equipment and delayed container delivery sometimes occurs. These drawbacks have caused operators additional

Figure 1.
Catch transshipment statistics for reefer container ships and reefer ships, 2008-2016
costs and even damage to the catch. According to the experience of the industry operators, in comparison with the freezer carrier vessels, cryopreservation containers often tend to suffer from temperature problems. Moreover, cryopreservation containers often do not have sufficient quantities, which leads to the problem of late deliveries. As things currently stand, most fishing vessels will, therefore, choose reefer container ships to transship their catches unless the problems of equipment and availability can be solved.

However, with the rapid development of high seas fisheries, numerous countries have found that there is a need to develop fisheries management and conservation mechanisms, and the FAO has consequently adopted the Code of Conduct for Responsible Fisheries and other international protocols for the conservation and management of fishery resources at the international level (Hsueh, 2004). In recent years, due to the restrictive measures adopted by international management organizations, the rising price of oil, as well as the fact that almost 53 per cent of the fisheries stocks are fully exploited and 32 per cent of fisheries stocks are either over-exploited, depleted or recovering from depletion (FAO, 2010). Catches in many fisheries have decreased significantly. Moreover, rising fishery access fees and related costs in coastal states, the threat of Somalian pirates in the Indian Ocean and other business issues have forced many fishing companies with poor cost control to shut down. According to Liu (2011), the far seas longline tuna fishery is an industry with “three highs,” namely, high risk, high investment and high technology. In the past, when catches were good, many unreasonable fees and various other derivative costs could be accepted for the sake of convenience. Times have changed, however, and how to control costs has become a major issue directly affecting the development of the far seas longline fishing industry in Taiwan.

It is known that Taiwan’s far seas longline tuna industry is currently facing growing competition and pressure in the international environment. According to the FAO (2012), factors affecting fishery trade include production and transportation costs, and shifts in the prices of fishery products and alternative products. In the past, the majority of Taiwanese tuna fishing vessels transshipped their catches by frozen transport ships at sea or by reefer container vessels in port. Nowadays, however, operators cannot freely select their means of transporting their catches. Complex and burdensome policies and economic factors have
imposed even greater operating cost burdens and influenced the choice of transportation. When operators face new difficulties and challenges, apart from continuing to improve the efficiency of the operation of fishing vessels, operators must also change their refrigerated transport decisions, and this inevitable change forms an important motivation for this study.

This paper seeks to explore factors that may affect the choice of cold chain transportation models from the perspectives of industry operators. As shown in Figure 3, one difference between the transport of far seas longline tuna catch and the transport of other general cargo is that fishing vessels can choose to transfer their catches in port, or at sea to reefer carriers, and can also choose to enter port and use reefer container ships to transport their frozen tuna.

The four purposes of this study are:

(1) to understand the development and the current status of Taiwan’s far seas longline fishing industries through a review of the literature and interviews;

(2) to investigate the attitude of Taiwanese fishing vessel operators fishing in the Indian Ocean concerning the use of transportation under the influence of various factors;

(3) to analyze the relationship between changes in the transportation behavior of Taiwanese fishing vessel operators and various factors; and

(4) to provide suggestions to government and industry associations concerning the development of viable response strategies for the far seas longline tuna industry and reference information for use in negotiations.

2. Cold chains
According to the International Refrigeration Dictionary, which was published by the International Institute of Refrigeration (2008), “cold chain” is defined as the use of cryopreservation to preserve perishable products through successive stages extending from the start of production to final consumption. The Cold Chain Association (2013) considers a cold chain to be an entire supply chain throughout the stages of production, storage and distribution of goods, where a certain degree of temperature control is required to maintain the characteristics of products. This study considers that a cold chain refers to the product process from the beginning of production to the end user when the entire transport process must be subject to temperature control to avoid damage or destruction of product quality.

Figure 3.
Conceptual map of frozen tuna transshipment options
How to maintain the temperature throughout the entire refrigerated supply chain is the crucial element that forms the basis of all cold chains, and is the most difficult issue to resolve in the development of a cold chain.

2.1 Development of ultra-low temperature frozen foods

As economic and living standards are going up, the quality requirements for tuna sashimi have also continued to increase. Low-temperature freezing is the only effective way to prevent spoilage of fishery products and ensure that the taste and color requirements are met. This need has driven the development of ultra-low-temperature refrigeration systems. In the early days, coastal tuna fishing boats would fill their fish tanks with crushed ice to prevent spoilage of their catch and keep the fish fresh; this is called the “ice refrigeration method.” However, this method can only attain temperatures near the freezing point. It can preserve the freshness of fish for only a limited amount of time that is typically one-two weeks. As more and more distant fishing zones had developed, fishing vessels began to rely on the use of freezers. This freezing method can attain temperatures ranging from the freezing point to −5°C. It is sufficient to kill bacteria, stop biochemical reactions in fishes, and prevent spoilage of fishes. Nevertheless, this method can merely prevent spoilage of fishes. It cannot preserve the original freshness, taste and color of fishes. To further improve the quality of tuna, complete freezing is necessary.

The longline tuna industry in Taiwan has largely inherited the Japanese technology. To ensure that tuna is kept as fresh as when it was first caught, freezing technology has to make breakthroughs and improvements continuously (Hsueh, 2004). As shown in Table I, from 1950 until present, the freezer compartments of fishing boats and the cold storage warehouses in which fishes are stored have continuously improved their storage environment. Nowadays, after the catches have been undergone simple pre-processing, they are placed in a rapid freezing chamber at a temperature of −60°C to −65°C. The fishes begin to freeze at a temperature of around −2°C, and freeze completely when its core temperature has fallen to −50°C. The fishes are then passed through cold water to cause a thin layer of ice to be formed on fishes. The ice layer serves to protect the fishes by cutting off the contact from the air. The fishes are finally moved to a storage hold at a temperature of −55 to −60°C. Chow (1989) points out that, while tuna is frozen at a temperature of −10 to −20°C, it will turn brown at an accelerating rate, i.e. from freezing to a temperature of −60°C. Storage at a temperature of under −60°C is an ideal situation to prevent changes and deterioration of tuna. To be able to transport frozen tuna fish and other aquatic products in the best conditions,

<table>
<thead>
<tr>
<th>Period</th>
<th>Freezer compartment</th>
<th>Fish warehouse</th>
</tr>
</thead>
<tbody>
<tr>
<td>1950 ~ 1955</td>
<td>−25 ~ −30°C</td>
<td>−15 ~ −20°C</td>
</tr>
<tr>
<td>1955 ~ 1960</td>
<td>−30 ~ −35°C</td>
<td>−20 ~ −35°C</td>
</tr>
<tr>
<td>1960 ~ 1965</td>
<td>−35 ~ −40°C</td>
<td>−25 ~ −30°C</td>
</tr>
<tr>
<td>1965 ~ 1968</td>
<td>−40 ~ −45°C</td>
<td>−35 ~ −40°C</td>
</tr>
<tr>
<td>1968 ~ 1970</td>
<td>−45 ~ −50°C</td>
<td>−40 ~ −45°C</td>
</tr>
<tr>
<td>1970 ~ 1972</td>
<td>−50 ~ −55°C</td>
<td>−45 ~ −50°C</td>
</tr>
<tr>
<td>1972 ~ 1980</td>
<td>−55 ~ −60°C</td>
<td>−50 ~ −55°C</td>
</tr>
<tr>
<td>After 1980</td>
<td>−60 ~ −65°C</td>
<td>−55 ~ −60°C</td>
</tr>
</tbody>
</table>

frozen and reefer container transport ships are gradually adopting ultra-low-temperature freezer technology which can ensure the catches to be preserved during transportation.

2.2 Overview of the frozen tuna supply chain
Tuna is one of Japan’s favorite types of fish, and most tuna are eaten in the form of sashimi in Japan (Sakai et al., 2007). According to the FAO, Japan accounts for almost all of the frozen tuna sashimi market. Japanese-owned tuna fishing vessels account for the catch of slightly over 200,000 tons of tuna consumed domestically, and roughly another 400,000 tons have to be imported to Japan (Miyake, 2010). Due to the fact that the freshness of tuna needed for sashimi can be maintained through refrigerated transport, Japan serves as the final market for almost the entire frozen tuna supply chain. After processing on far seas, longline tuna vessels operating offshore, frozen tuna can be transported to Japan by fishing vessels, reefer ships and reefer container ships. The current frozen tuna supply chain consists of two models, as shown in Figure 4:

(1) **Domestic**: Tuna caught by domestic longliners is unloaded at a home port and immediately placed in storage. The fish unloaded at landing port markets can be sold locally through auctions, or prepared and sent to central markets. Some are sold directly to buyers or wholesalers, and sometimes to large-scale retailers.

(2) **Imported**: Tuna caught by foreign fishing vessels (such as Taiwan, South Korea, China and others) is unloaded from transshipment reefer ships or reefer container ships into ultra-low-temperature frozen storage areas by importers. These large-scale importers buy fishes directly from fishing vessels. Most of the tuna kept in cold storage by the buyers or traders is sold directly to large-scale retailers, including chain retailers and supermarkets.

2.3 Cold chain transport methods
According to Dellacasa (1987), the maritime transport of refrigerated goods consisting of the transport of perishable foods from the producers to the consumers is an important part of cold chain transport. While there are many types of cold chain transports, this paper examines only the main modes of transport for bulk frozen seafood, and thus the land and air transports are not discussed in this paper. Transports of frozen tuna and tuna-like species can generally be classified as three types, namely, far seas longline tuna vessels,

![Figure 4. Frozen tuna supply chain](image)

reefer ships and reefer container ships. The following is a summary of these modes of transportation:

2.3.1 Longline tuna fishing vessels. According to the Fishing Operations report 1996 issued by the FAO (2010), any vessel used or intended to be used for commercial exploitation of living marine resources, including mother ships and other vessels directly engaged in fishing operations, can be called “fishing vessels”. Powered fishing vessels engaged in fishing operations outside the 200-nautical-mile economic zone of Taiwan, including those operating in the economic zones of other countries are known as “far seas fishing vessels”. The longline fishing method generally involves many branch lines installed on a main line, with a baited hook at the end of each branch line, and the bait most commonly consisting of squid, Pacific saury, mackerel and sardines, etc. Fishing vessels using this fishing method are known as “longline fishing vessels”.

2.3.2 Reefer ships or refrigerated cargo carriers. Reefer ships are designed to carry perishable products requiring temperature control and must therefore have cargo refrigeration systems. Most reefer ships are used to carry fishes, fruits, vegetables, meats and dairy products, etc. Vessels which used to transport fish consist of live fish transport vessels and reefer ships. Since the development of reefer ships, they have helped to improve productivity of far seas longline tuna vessels. As fish can be transshipped at sea to consumer countries at an early date, reefer ships can improve fisheries management, reduce capacity problems and lessen the spoilage of catch due to loss of temperature control.

2.3.3 Reefer container ships. Reefer container ships carry cargo containers that have refrigeration equipment. The invention of refrigerated containers has enabled perishable products to be transported to distant places while maintaining their characteristics intact. The first use of reefer container ships was by Sea-Land, an American shipping company, in 1956. The vessels have since brought about a historic change in cargo transport and trade (Branch and Stopford, 2013). In terms of functions, reefer container ships can be classified as standard reefer container ships, gas control container ships, ultra-low-temperature reefer container ships and extremely-low-temperature cargo containers ships. Ultra-low-temperature reefer container ships can export tuna to Japan for sashimi at an ultra-low temperature of –60°C. For –25°C and –35°C reefer container ships, they can transport tuna for canning or uses other than as sashimi. As tuna has high economic value, the temperature problem may lead to an entire container of frozen tuna sashimi to become inedible. As a consequence, a container company or shipping company may send personnel to perform random testing of fish temperature ensuring that tuna has reached the standard ultra-low temperature, and avoiding the possibility of disputes (Figure 5).

Chen and Notteboom (2012) proposed that freezer vessels offer the advantages of shorter transport time and better temperature control, while reefer container ships offer lower transport costs and easier in-port transshipment. This study relied on the literatures and interviews to compile the operating advantages of the three commonly used modes of frozen tuna transport. However, fishing vessels are included for comparison purposes only, as tuna is very seldom unloaded directly from fishing vessels in Japan. As shown in Table II, the transshipment time of freezer carrier vessels have advantages enabling higher capital turnover rate, lower temperature risk, higher loading capacity, better mobility and other advantages. In contrast, reefer container ships offer low transport costs, no fuel costs and international control. While it can be seen why freezer carrier vessels are preferred by operators, in the wake of changes in the international environment, transport costs, fuel costs and the need for international control are causing operators to consider the use of reefer container ships.
3. Methodology

This study first sought to understand and analyze issues facing the industry, and then compile a questionnaire through interviews with experts in the industry. Finally, factor analysis and AHP analysis were used to analyze the factors affecting the choice of transport modes.

3.1 Factor analysis and the analytic hierarchy process

Factor analysis consists of a series of methods for identifying clusters of related variables, and is therefore an ideal technique for reducing numerous items into a more easily understood framework. Factor analysis involves the use of a data matrix produced from numerous individual cases or respondents.

The analytic hierarchy process (AHP) is most applicable to problems with unclear or multi-faceted standards. AHP involves collection of opinions from experts and managers, use of a nominal scale to perform pair-wise comparisons between factors, establishment of a pair comparison matrix and calculation of eigenvectors and eigenvalues. Eigenvectors display the rank of factors on one level and enable the evaluation of the relative weight of every indicator in a model. Furthermore, AHP can be used to analyze the consistency of a matrix by using a consistency index and consistency ratio to evaluate the level of consistency among the experts. Owing to the advantages of simplicity and easy operating

<table>
<thead>
<tr>
<th>Type item</th>
<th>Longline vessels</th>
<th>Freezer carriers</th>
<th>Reefer container vessels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation costs</td>
<td>–</td>
<td>Higher</td>
<td>Lower</td>
</tr>
<tr>
<td>Transport time</td>
<td>Normal</td>
<td>Short</td>
<td>Long</td>
</tr>
<tr>
<td>Capital turnover rate</td>
<td>Low</td>
<td>Higher</td>
<td>Lower</td>
</tr>
<tr>
<td>Fuel costs</td>
<td>High</td>
<td>Higher</td>
<td>–</td>
</tr>
<tr>
<td>Temperature risk</td>
<td>Normal</td>
<td>Lower</td>
<td>Higher</td>
</tr>
<tr>
<td>Loading</td>
<td>Normal</td>
<td>Higher</td>
<td>Lower</td>
</tr>
<tr>
<td>Flexibility</td>
<td>Good</td>
<td>Better</td>
<td>Lower</td>
</tr>
<tr>
<td>International control</td>
<td>Much</td>
<td>More</td>
<td>Less</td>
</tr>
</tbody>
</table>

Source: Chen and Notteboom (2012) and expert interviews
procedures, AHP is able to collect opinions of many experts at the same time and is considered one of the most optimal decision-making techniques.

After a hierarchy framework is established, pair-wise comparisons are performed between each layer’s decision factors. Taking upper layer factors as decision criteria, the relative importance of each pair of factors is then evaluated. If there are $N$ factors, an $n(n-1)/2$ pair-comparison matrix is made. Pair comparison of decision factors is used to create a comparative factor matrix, where $a_{ij}$ represents the results of the decision makers’ pair-wise comparison of decision factor $i$ and decision factor $j$, which expresses the decision makers’ degree of emphasis on each factor (Saaty, 1980).

3.2 Questionnaire design
With regard to the design of the two questionnaires in this paper, the first questionnaire sought to gather basic information, which included age, position, number of employees and job seniority. A Likert scale extending from 1 (extremely unimportant) to 7 (extremely important) was used in the design of the questionnaire. To determine the structure of the questionnaire, in addition to performing a review of fishing literature, interviews were conducted with personnel at the Indian Ocean longline tuna vessel operating companies.

The second questionnaire used the dimensions and assessment criteria determined also using in the first questionnaire. AHP was then used to assess the impact of the assessment criteria on cold chain transport mode choice. In accordance with Saaty (1980) and other studies, the maximum level of assessment factors on each level should not exceed seven, and three to five factors is appropriate in most research.

As for the subjects of the two questionnaire surveys, the first questionnaire was given to 70 fishing companies engaging in longline tuna vessel operations in the Indian Ocean. The subjects of the second questionnaire survey consisted of 25 persons affiliated with the Indian Ocean longline tuna fishing boat operators, industry associations, shipping companies transporting frozen catch and the Fisheries Administration, Council of Agriculture, which is the competent authority in charge of fisheries in Taiwan.

3.3 Selection factors for cold chain modes of transport
As there is little past literature concerning selection of cold chain transport modes, the majority of impact factors were acquired from personal interviews with experts at various tuna fishing companies at the port of Kaohsiung.

The total of 16 cold chain mode selection factors comprised:

1. fishing vessel operating location;
2. fishing season;
3. annual maintenance schedule;
4. reefer ship compliance;
5. level of transshipment costs;
6. changes in annual catch quotas;
7. changes in the market price of fish;
8. reefer container vessel schedules;
9. international management organization regulatory restrictions;
10. Regional Observer Program impact;
11. reduction in fishing grounds;
4. Results

4.1 First questionnaire data and statistics
The first questionnaire was completed by people who were operating large-scale longline tuna fishing vessels in the Indian Ocean in Taiwanese companies; 70 valid samples were obtained from the 70 questionnaires, which represented a 100 per cent recovery rate. The basic information gathered by this questionnaire can be summarized as follows:

- Most of the participants were between 36 to 45 years of age (77 per cent).
- Most had been employed for from 16 to 25 years (67 per cent).
- Most held the job title of shipping manager (64 per cent) (see Table III).

4.2 Factor analysis
Factor analysis can be used to derive a relatively small number of factors, which in turn can be used to represent relationships among sets of many interrelated variables. According to the KMO decision criteria proposed by Kaiser (1974), an acceptable value for the KMO test was greater than 0.5. The results indicated a KMO value of sampling adequacy of 0.817, which was deemed appropriate for analytical purposes. The first stage of factor analysis consisted of determining the strength of the correlation among the 16 factors as determined by the correlation coefficients of each pairs of factors. A matrix was generated automatically using SPSS software. The factor groupings based on varimax rotation are presented and

<table>
<thead>
<tr>
<th>Basic information</th>
<th>Characteristics</th>
<th>Frequency</th>
<th>(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>41 ~ 45</td>
<td>22</td>
<td>31.42</td>
</tr>
<tr>
<td></td>
<td>36 ~ 40</td>
<td>16</td>
<td>22.85</td>
</tr>
<tr>
<td></td>
<td>46 ~ 50</td>
<td>16</td>
<td>22.85</td>
</tr>
<tr>
<td></td>
<td>31 ~ 35</td>
<td>9</td>
<td>12.85</td>
</tr>
<tr>
<td></td>
<td>56 ~ 60</td>
<td>5</td>
<td>7.14</td>
</tr>
<tr>
<td></td>
<td>51 ~ 55</td>
<td>2</td>
<td>2.85</td>
</tr>
<tr>
<td>Years of seniority</td>
<td>16 ~ 20</td>
<td>31</td>
<td>44.28</td>
</tr>
<tr>
<td></td>
<td>21 ~ 25</td>
<td>16</td>
<td>22.85</td>
</tr>
<tr>
<td></td>
<td>11 ~ 15</td>
<td>10</td>
<td>14.28</td>
</tr>
<tr>
<td></td>
<td>6 ~ 10</td>
<td>8</td>
<td>11.42</td>
</tr>
<tr>
<td></td>
<td>26 or more</td>
<td>5</td>
<td>7.14</td>
</tr>
<tr>
<td>Number of employees in company</td>
<td>200 or more</td>
<td>32</td>
<td>45.71</td>
</tr>
<tr>
<td></td>
<td>151 ~ 175</td>
<td>17</td>
<td>24.28</td>
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<tr>
<td></td>
<td>51 ~ 75</td>
<td>11</td>
<td>15.71</td>
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<td></td>
<td>76 ~ 100</td>
<td>8</td>
<td>11.42</td>
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<tr>
<td></td>
<td>26 ~ 50</td>
<td>2</td>
<td>2.85</td>
</tr>
<tr>
<td>Job title</td>
<td>Shipping manager</td>
<td>45</td>
<td>64.28</td>
</tr>
<tr>
<td></td>
<td>General staff</td>
<td>12</td>
<td>17.14</td>
</tr>
<tr>
<td></td>
<td>President</td>
<td>11</td>
<td>15.71</td>
</tr>
<tr>
<td></td>
<td>General manager</td>
<td>2</td>
<td>2.85</td>
</tr>
</tbody>
</table>

Table III. Profile of respondents
reveal that the four components account for 78.82 per cent of the sample variance. As shown in Table IV, four components with eigenvalues greater than 1 were extracted. Each of the factors belonged to only one of the components, with the value of factor loading exceeding 0.5. To make them more meaningful, the four components were renamed:

1. fishing vessel operating strategies;
2. fishing vessel operating costs;
3. international business environment; and
4. fishing vessel operating efficiency.

With regard to reliability analysis, Cronbach’s alpha ranged from 0.78 to 0.94. A review of literature concerning reliability revealed that a reliability coefficient of 0.70 or higher is considered satisfactory. With regard to validity analysis, the proposed independent variables and items included in each variable were finalized based on suggestions from the respondents, which improved the content validity.

4.3 Impact of assessment criteria on cold chain transportation choices
Using data from the first questionnaire, a hierarchical analysis was performed of the four main dimensions:

1. international business environment;
2. fishing vessel operating costs;
3. fishing vessel operating strategies;
4. fishing vessel operating efficiency.

<table>
<thead>
<tr>
<th>Main factors</th>
<th>Assessment criteria</th>
<th>Load factor</th>
<th>Eigenvalue</th>
<th>Cumulative explained variation (%)</th>
<th>Cronbach's $\alpha$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fishing vessel operating strategies</td>
<td>Fishing vessel operating location</td>
<td>0.916</td>
<td>3.734</td>
<td>23.34</td>
<td>0.942</td>
</tr>
<tr>
<td></td>
<td>Fishing season</td>
<td>0.906</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Annual maintenance schedule</td>
<td>0.901</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reefer ship compliance</td>
<td>0.895</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Level of transshipment costs</td>
<td>0.942</td>
<td>3.395</td>
<td>44.56</td>
<td>0.917</td>
</tr>
<tr>
<td></td>
<td>Changes in annual catch quotas</td>
<td>0.887</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Changes in the market price of fish</td>
<td>0.876</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reefer container vessel schedules</td>
<td>0.865</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>International business environment</td>
<td>International management organization</td>
<td>0.869</td>
<td>3.004</td>
<td>63.33</td>
<td>0.866</td>
</tr>
<tr>
<td></td>
<td>regulatory restrictions</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Effect of Regional Observer Program</td>
<td>0.848</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reduction in Fishing grounds</td>
<td>0.837</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rampant Somalian piracy</td>
<td>0.731</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Fishing vessel operating efficiency</td>
<td>Amount of catches</td>
<td>0.865</td>
<td>2.479</td>
<td>78.82</td>
<td>0.785</td>
</tr>
<tr>
<td></td>
<td>Catch load capacity</td>
<td>0.829</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Labor shortages</td>
<td>0.575</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fishing vessel resources</td>
<td>0.534</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table IV. Summary of factor analysis of assessment criteria for cold chain transport mode selection

Cold supply chain of longline tuna
fishing vessel operating strategies; and
fishing vessel operating efficiency, and the 16 assessment criteria:

- fishing vessel operating location;
- fishing season;
- annual maintenance schedule;
- reefer ship compliance;
- level of transshipment costs;
- changes in annual catch quotas;
- changes in the market price of fish;
- reefer container vessel schedules;
- international management organization regulatory restrictions;
- effect of the Regional Observer Program;
- reduction in fishing ground;
- rampant Somalian piracy;
- amount of catches;
- catch load capacity;
- labor shortages; and
- fishing vessel resources (Figure 6).

4.4 Analysis of basic data from the second questionnaire
The second questionnaire was administered to people who were affiliated with longline tuna fishing boat operators, Tuna Association, reefer ship operators and the Fisheries Administration, Council of Agriculture. This survey was implemented through emails and in-person interviews conducted by the authors; 28 valid samples were obtained from the 28 questionnaires, which represent a 100 per cent recovery rate. As three questionnaires did not
pass the consistency test \((C.R. \leq 0.01)\), there was a final total of 25 valid questionnaires. The basic respondent data obtained from this questionnaire are summarized as follows:

- Most respondents had seniority of from 11 to 20 years (68 per cent).
- Most had a job title of manager (60 per cent).

4.4.1 AHP analysis. Analysis of the AHP expert questionnaire was performed using Expert Choice software to calculate the weight value and implement consistency testing. Following assessment of the weighting results for the four dimensions and 16 assessment criteria, the fact that the C.I. and C.R. values were less than the 0.1 recommended by Saaty (1980) indicated that the valid questionnaires possessed consistency.

Table V shows that all the experts agreed that “Fishing vessels’ operating costs” had the greatest impact on choice of cold chain transportation options, and was followed by “Fishing vessel operating efficiency,” “International business environment” and “Fishing Operations strategy.”

See Table VI for the experts’ weighting analysis of factors influencing cold chain transport mode decisions on the second level.

- amount of catches;
- changes in the market price of fish;
- fishing vessel operating location;
- level of transshipment costs;
- international management organization regulatory restrictions;
- rampant Somali piracy;
- changes in annual catch quotas; and
- catch load capacity.

It can be seen from Table VII that the experts still consider reefer ships to be the preferred means of frozen catch transshipment in view of their assessment of all dimensions. However, among the assessment criteria, Rampant Somali piracy, level of transshipment costs, annual maintenance schedule and labor shortages tend to make the use of reefer container ships more advantageous.

This result can be understood in the context of today’s increasingly difficult fisheries management in the wake of changes in the international environment. According to Chen and Notteboom (2012), while reefer container ships are gradually capturing a share of the market held by reefer ships, the advantages of reefer ships cannot be entirely replaced. The market is, therefore, likely to reach an equilibrium, where reefer ships will provide high-value services and reefer container ships will offer more cost-oriented services.

<table>
<thead>
<tr>
<th>Main factors</th>
<th>Weight</th>
<th>Rank</th>
</tr>
</thead>
<tbody>
<tr>
<td>International business environment</td>
<td>0.201</td>
<td>3</td>
</tr>
<tr>
<td>Fishing vessel operating costs</td>
<td>0.326</td>
<td>1</td>
</tr>
<tr>
<td>Fishing Operations strategy</td>
<td>0.195</td>
<td>4</td>
</tr>
<tr>
<td>Fishing vessel operating efficiency</td>
<td>0.277</td>
<td>2</td>
</tr>
</tbody>
</table>

Note: All samples passed the consistency ratio \((C.R. \leq 0.01)\)
### Table VI.
Weights and rank of assessment criteria on the second level

<table>
<thead>
<tr>
<th>Main factors</th>
<th>Weights</th>
<th>Sub-factors</th>
<th>All experts</th>
<th>Overall weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>International business environment</td>
<td>0.201</td>
<td>International management organization regulatory restrictions</td>
<td>0.352 1</td>
<td>0.071 5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Effect of Regional Observer Program</td>
<td>0.122 4</td>
<td>0.025 15</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reduction in fishing ground</td>
<td>0.222 3</td>
<td>0.045 11</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rampant Somalian piracy</td>
<td>0.304 2</td>
<td>0.061 6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Changes in market price of fish</td>
<td>0.461 1</td>
<td>0.150 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Changes in annual catch quotas</td>
<td>0.174 3</td>
<td>0.057 7</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reefer container vessel schedules</td>
<td>0.138 4</td>
<td>0.045 10</td>
</tr>
<tr>
<td>Fishing vessel operating costs</td>
<td>0.326</td>
<td>Level of transshipment costs</td>
<td>0.227 2</td>
<td>0.074 4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fishing vessel operating location</td>
<td>0.470 1</td>
<td>0.092 3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Annual maintenance schedule</td>
<td>0.104 4</td>
<td>0.020 16</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reefer ship compliance</td>
<td>0.165 3</td>
<td>0.032 13</td>
</tr>
<tr>
<td>Fishing Operations strategy</td>
<td>0.195</td>
<td>Fishing season</td>
<td>0.292 2</td>
<td>0.051 9</td>
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<tr>
<td></td>
<td></td>
<td>Amount of catches</td>
<td>0.561 1</td>
<td>0.155 1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fishing vessel resources</td>
<td>0.149 3</td>
<td>0.041 12</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Labor shortages</td>
<td>0.104 4</td>
<td>0.029 14</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Catch load capacity</td>
<td>0.186 2</td>
<td>0.052 8</td>
</tr>
</tbody>
</table>

### Table VII.
Overall relative weight and rank of cold chain transport modes

<table>
<thead>
<tr>
<th>Assessment criteria</th>
<th>Evaluation criteria relative weights</th>
<th>Weights of modes of transport</th>
<th>Overall weights of modes of transport</th>
</tr>
</thead>
<tbody>
<tr>
<td>International management organization regulatory restrictions</td>
<td>0.071 0.674 0.326</td>
<td>0.048 0.023</td>
<td></td>
</tr>
<tr>
<td>Effect of Regional Observer Program</td>
<td>0.025 0.588 0.412</td>
<td>0.014 0.010</td>
<td></td>
</tr>
<tr>
<td>Reduction in fishing ground</td>
<td>0.045 0.545 0.455</td>
<td>0.024 0.020</td>
<td></td>
</tr>
<tr>
<td>Rampant Somalian piracy</td>
<td>0.061 0.423 0.577</td>
<td>0.026 0.035</td>
<td></td>
</tr>
<tr>
<td>Changes in the market price of fish</td>
<td>0.150 0.570 0.430</td>
<td>0.086 0.065</td>
<td></td>
</tr>
<tr>
<td>Changes in annual catch quotas</td>
<td>0.057 0.571 0.429</td>
<td>0.032 0.024</td>
<td></td>
</tr>
<tr>
<td>Reefer container vessel schedules</td>
<td>0.045 0.621 0.379</td>
<td>0.028 0.017</td>
<td></td>
</tr>
<tr>
<td>Level of transshipment costs</td>
<td>0.074 0.390 0.610</td>
<td>0.029 0.045</td>
<td></td>
</tr>
<tr>
<td>Fishing vessel operating location</td>
<td>0.092 0.749 0.251</td>
<td>0.069 0.023</td>
<td></td>
</tr>
<tr>
<td>Annual maintenance schedule</td>
<td>0.020 0.247 0.753</td>
<td>0.005 0.015</td>
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</tr>
<tr>
<td>Reefer ship compliance</td>
<td>0.032 0.622 0.378</td>
<td>0.020 0.012</td>
<td></td>
</tr>
<tr>
<td>Fishing season</td>
<td>0.051 0.653 0.347</td>
<td>0.033 0.018</td>
<td></td>
</tr>
<tr>
<td>Amount of catches</td>
<td>0.155 0.755 0.245</td>
<td>0.117 0.038</td>
<td></td>
</tr>
<tr>
<td>Fishing vessel resources</td>
<td>0.041 0.627 0.373</td>
<td>0.026 0.015</td>
<td></td>
</tr>
<tr>
<td>Labor shortages</td>
<td>0.029 0.452 0.548</td>
<td>0.013 0.016</td>
<td></td>
</tr>
<tr>
<td>Catch load capacity</td>
<td>0.052 0.740 0.260</td>
<td>0.038 0.013</td>
<td></td>
</tr>
</tbody>
</table>
5. Conclusions
This paper seeks to investigate factors affecting the choice of cold chain mode of transport from the perspective of Taiwanese companies operating longline tuna fishing vessels in the Indian Ocean, which are chiefly motivated by the need to reduce operating costs, and also looks at their choices of means of transport. In order of their degree of influence, the 16 chief factors affecting this decision were:

1. fishing vessel operating location;
2. fishing season;
3. annual maintenance schedule;
4. reefer ship compliance;
5. level of transshipment costs;
6. changes in annual catch quotas;
7. changes in the market price of fish;
8. reefer container vessel schedules;
9. international management organization regulatory restrictions;
10. effect of Regional Observer Program;
11. reduction in fishing ground;
12. rampant Somalian piracy;
13. amount of catches;
14. catch load capacity;
15. labor shortages; and
16. fishing vessel resources.

These factors were also the assessment criteria used by the industry to evaluate cold chain modes of transport.

Furthermore, the study found that all the experts agreed that the dimension of “Fishing vessel operating costs” was the most important consideration when choosing cold chain mode of transport, and was followed by “Fishing vessel operating efficiency,” “International business environment” and finally, “Fishing business strategy.” The eight assessment criteria that had a major impact on cold chain mode of transport decisions were:

1. amount of catches;
2. changes in the market price of fish;
3. fishing vessel operating location;
4. level of transshipment costs;
5. international management organization regulatory restrictions;
6. rampant Somalian piracy;
7. changes in annual catch quotas; and
8. catch load capacity.

Through an assessment of the dimensions, this study also found that reefer ships are still the preferred means of transshipping frozen catch. However, the assessment criteria “Rampant Somalian piracy,” which is connected with the international environment, “Level of transshipment costs,” which is connected with fishing boat operating costs, “Annual
maintenance schedule,” which is connected with vessel operating strategies, and “Labor shortages,” which is connected with fishing boat operating efficiency, all tend to make reefer container ships the preferred means of transport.

As the problem of piracy cannot be solved in the short term, plus international oil prices and other relevant costs are likely to continue gradually increasing, reefer container ships will probably be increasingly used for the transshipment of frozen catch in the future. It can be recommended that reefer container ship operators should increase container volume, and should also strengthen their quality and temperature control.

Another finding of this study is that, in view of the prevailing international circumstances, the fishing industry is not as dependent on reefer ships as in the past, which is also a reflection of the increasing operating costs of the fishing industry in the Indian Ocean. It is, therefore, recommended that the government and industry associations should provide subsidies and incentives for those operators that participate in measures promoting compliance with international policies, which will enhance the competitiveness of our fishing vessels in the Indian Ocean.

5.1 Recommendations

5.1.1 Proposals for vessel operators. The main conclusion of this study is that “Amount of catch” and the “Changes in the market price of fish” are the two most important considerations when choosing cold chain mode of transport. Although the sustainable management strategies of international fisheries management organizations are still insufficient to compensate for the fishing capacity of boats from various countries, we can still expect that fisheries resources will slowly recover in the future.

Strategic use of mode of transport: The use of reefer container ships to transship frozen tuna can prolong transport time, which can strategically ensure that supply cannot meet demand. This will allow a break from the customary practice prevailing in the past in which reefer ships would quickly transship tuna to Japan, which often cost excessively low market fish prices.

5.1.2 Proposals for the industry association. Strategic partnerships with shipping companies: Association members can take advantage of their group bargaining power to negotiate satisfactory cooperation arrangements with container ship operators, such as by ensuring the availability sufficient quantity of containers, which will help the industry to reduce costs and address issues such as the lack of available containers.

5.1.3 Proposals for the container shipping industry. The manufacture of superior reefer container ships: While this study found that the threat of piracy was a factor motivating the choice of reefer container ships, this problem cannot be resolved in the short term. As international oil prices and other relevant costs have been gradually increasing, the use of reefer container ships to transport catch has also been increasing. We, therefore, recommend that container shipping companies increase the number of ultra-low-temperature reefer containers that can be carried on their vessels.

Improvement of the quality of in-service reefer container ships: Since the longline fishing industry has long complained about the temperature quality control of reefer container ships, reefer ships are still the preferred means of transshipping frozen catch. We recommend that shipping companies replace older reefer container ships and improve their service, which will facilitate their role in the development of cold chain logistics.

Development of seafood industry clusters: The ultra-low-temperature reefer container market is an area where container shipping companies can effectively invest. Apart from demand for ultra-low-temperature containers, the far seas fisheries industry cluster located
at Qianzhen in Kaohsiung also has great need for general supplies and bait that can be shipped using reefer container ships.

5.1.4 Proposals concerning government policies. Strictly control of the quality of frozen tuna: Because some of the fishing boats in Taiwan have inadequate refrigeration capacity, some poor-quality products are sold to the Japanese market, which are of low prices. We, therefore, recommend that the government should limit the issuance of certificate of origin. This will impact on the whole sashimi market and maintain the competitiveness of fishing vessels in Taiwan.

Designation of a fishery logistics zone: To better leverage the advantages of Qianzhen fishing port in Kaohsiung, we recommend that government fisheries agencies and the Taiwan International Ports Corporation Ltd. establish a fishery low-temperature logistics zone where companies interested in transshipment can build ultra-low-temperature processing facilities for the purpose of re-export and the creation of added value.

Establishment of on-shore port power equipment: As over 100 fishing vessels rely on Qianzhen fishing port for supplies and maintenance, we recommend that on-shore power equipment be installed. Apart from effectively reducing air pollution and noise in the Kaohsiung area, this will enable operators to power refrigeration equipment on fishing vessels using on-shore power supplies. It will also ease the waiting time and cost of the reefer container ships.

Appropriately adjusting rules and regulations: The longline tuna industry requires a huge quantity of bait. In addition to the using domestic offshore mackerel, the industry also relies on the import of bait (such as sardines). We, therefore, recommend that fisheries agencies, customs and the Taiwan International Ports Corporation arrange for the tariff-free import of frozen bait, not for human consumption, to the port of Kaohsiung. Apart from reducing the cost of transporting frozen bait in reefer ships, this will also increase the import/export container volume at the port of Kaohsiung.

5.1.5 Proposals for academic researchers. Increased study of the cold chain logistics and seafood products: While the development of cold chain logistics is in a growing trend, and the consumption of seafood is also growing, there is little domestic literature on these areas. We, therefore, suggest that more academic researches on cold chain logistics and aquatic products should be encouraged.

5.1.6 Proposals concerning future research directions. This study takes the perspective of Taiwanese companies operating longline tuna fishing vessels in the Indian Ocean. However, it does not specifically discuss the operating situation of albacore fishing vessels in Taiwan, nor does it examine fishing vessels operating in the Pacific and Atlantic Oceans. Furthermore, a similar approach can be used to investigate the situation in the purse seine and squid fisheries.

References


Further reading

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Hong Kong maritime arbitration under the Arbitration Ordinance 2011

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Bing Chan
Division of Business and Management, Beijing Normal University – Hong Kong Baptist University United International College, Zhuhai, China

Abstract

Purpose – In 2011, the new Arbitration Ordinance took effect in Hong Kong. This paper aims to discuss the new features on maritime arbitration.

Design/methodology/approach – The relevant provisions of the Arbitration Ordinance 2011 and the legal cases are examined.

Findings – Hong Kong is a first class maritime arbitration centre in the Asia Pacific Region.

Originality/value – This paper is one of the very few general reviews of the maritime arbitration under the Arbitration Ordinance 2011.

Keywords Hong Kong, Maritime arbitration, Maritime disputes

Paper type General review

1. Introduction

In the shipping industry, international arbitration is the most commonly used dispute resolution mechanism. Maritime disputes have several special features. First, they are international disputes involving two or more parties in different countries. Second, the monetary amount of the disputes is high. Third, the disputes would be better resolved by someone who has shipping knowledge. Some typical contractual shipping disputes are claims for cargo damage or loss, wrongful delivery of goods, shortage of bulk cargo, etc. Typical tortious maritime cases are ship collisions, oil pollutions, etc. Thus, the use of maritime arbitration to resolve shipping disputes would be better than the use of traditional judicial litigation.

Hong Kong has special advantages as a centre in maritime arbitration. As Hong Kong is an international maritime centre, it is much easier to have qualified arbitrators who are experts in different areas of the maritime industry, such as marine insurers, average adjusters, shipping lawyers etc. It also has a long history of an independent judicial system with a good support from the common law and written legislation. As far as languages are concerned, the arbitrators are able to speak not only English but also Chinese languages, including Mandarin and Cantonese which are commonly used in the commercial world.
Moreover, Chinese people in Mainland China, Hong Kong and Taiwan have a philosophy to maintain social harmony in resolving disputes. Thus, arbitration is preferable than litigation to resolve disputes (Wong, 2000).

2. Hong Kong arbitration law
The new Arbitration Ordinance (Cap. 609, the Ordinance) (AO) was enacted by the Legislative Council on 10 November 2010, and the new law came into effect on 1 June 2011, replacing the old Arbitration Ordinance (Cap. 341, the old AO).

In 2011, 65 per cent (representing 178 cases) of all arbitration cases handled by the Hong Kong International Arbitration Centre (HKIAC) were of international nature.

One of the advantages of using arbitration to resolve disputes is the confidentiality of arbitration. Section 18 of the ordinance provides that, unless otherwise agreed by the parties or provided by the exceptions in Sub-section 2 which are primarily relating to disclosure of awards in the context of court proceedings in Hong Kong and abroad or regulatory matters, the disclosure of information relating to arbitral proceedings or awards is prohibited. In general, arbitral proceedings under the ordinance are not to be heard in open court. The exception is that the court may order the proceedings to be heard in an open court on the application of any party or if, in any particular case, the court is satisfied that the proceedings ought to be heard in an open court (Section 17, AO).

2.1 New features
When arbitrations were governed by the old AO, they were classified as domestic and international arbitrations. As far as the international arbitration regime is concerned, the old AO was based on the Model Law on International Commercial Arbitration of the United Nations Commission on International Trade Law (the Model Law) which formed the Fifth Schedule to the legislation since 1990.

The main feature of the ordinance is the removal of the distinction between domestic and international arbitrations. The ordinance provides a single, unified regime based on the Model Law, but with a number of modifications and additions tailored to suit the requirements of Hong Kong (Section 4, AO). This approach aligns the arbitration regime in Hong Kong more closely to international practices.

The structure of the ordinance generally follows the same order as the Model Law and refers to each article regarding its application or non-application. This makes the ordinance generally easier for practitioners and parties, particularly those from outside Hong Kong who are more familiar with the Model Law.

3. Maritime arbitration
The HKIAC was established in 1985 to promote the use of arbitration and other forms of alternative dispute resolutions in Hong Kong. It is completely independent of the Hong Kong Government and governed by its council headed by a chairperson. The work of the HKIAC is conducted through its various committees.

The HKIAC has handled maritime cases since its establishment. Moreover, a division of the HKIAC, the Hong Kong Maritime Arbitration Group (MAG), which is specialised in maritime arbitration, was formed in 2000. It is formed by a group of professionals residing in Hong Kong who are prepared to sit as arbitrators of maritime disputes. A separate list of 33 maritime arbitrators (as of 1 June 2017) is maintained for this purpose. A full list of maritime arbitrators can be downloaded from the website of the Hong Kong Shipowners Association.
Table I shows the total number of cases handled by the HKIAC and the number of maritime arbitration (MA) cases in the period from 1985 to 2007 (Moser and Cheng, 2014).

Between 1985 and 2007, the total arbitration cases were 4,510. There were 502 maritime cases, ranking third in number of arbitration cases in Hong Kong. Ranking the first was construction with 2,066 cases and the second was commercial with 1,059 cases (Moser and Cheng, 2008).

Table II shows the number and percentage of maritime cases between 2010 and 2016, which was in the range of 15 to 20 per cent, except in 2011 and 2012 when the percentage went up to 38 per cent.

In terms of the total amount of claims in arbitration cases, the amount was US$2.8bn in 2014, US$6.2bn in 2015 and US$2.5bn in 2016.

3.1 MAG Model Arbitration Clause

The MAG of the HKIAC has drafted a Model Maritime Arbitration Clause (HKIAC, 2014) as follows:

This Contract shall be governed by and construed in accordance with English/Hong Kong law and any dispute arising out of or in connection with this Contract shall be referred to arbitration in Hong Kong in accordance with the Arbitration Ordinance Cap. 609 or any statutory reenactment or modification thereof save to the extent necessary to give effect to the provisions of this clause.

The arbitration reference shall be to three arbitrators:

(i) A party wishing to refer a dispute to arbitration shall appoint its arbitrator and send notice of such appointment in writing to the other party requiring the other party to appoint its own arbitrator within 14 calendar days of that notice, and stating it will appoint its arbitrator as sole arbitrator unless the other party appoints its own arbitrator and gives notice that it has done so within the 14 days specified.

If the other party does not appoint its own arbitrator and give notice that it has done so within the 14 days specified, the party referring a dispute to arbitration may, without the requirement of any further prior notice to the other party, appoint its arbitrator as sole arbitrator and shall advise the other party accordingly. The award of a sole arbitrator shall be binding on both parties as if he/she had been appointed by agreement.

(ii) Where each party appoints its own arbitrator, then the two arbitrators so appointed may proceed with the arbitration and at any time thereafter appoint a third arbitrator so long as they do so before any substantive hearing or forthwith in the event that they cannot agree on any matter relating to the arbitration. If the said two arbitrators do not appoint a third within 14 days of one calling upon the other to do so, or if they are in disagreement as to the third arbitrator, either arbitrator or a party shall apply to the Hong Kong International Arbitration Centre (HKIAC) for the appointment of the third arbitrator.

The language used in the arbitration shall be English.

Nothing herein shall prevent the parties agreeing in writing to vary these provisions to provide for the appointment of a sole arbitrator and, if necessary, for the HKIAC to exercise its statutory power to appoint the sole arbitrator if the parties cannot agree on the appointment.
### Table I.
The number of maritime arbitration cases between 1985 and 2007

<table>
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<td>9</td>
<td>28</td>
<td>25</td>
<td>48</td>
<td>18</td>
</tr>
</tbody>
</table>

**Note:** *Hong Kong was attacked by SARS in 2003*

**Source:** Moser, 2008
This arbitration shall be conducted in accordance with the HKIAC Small Claims Procedure current at the time when the arbitration proceedings are commenced provided that neither the claim nor any counterclaim exceeds the limit provided for in such procedure.

* - Delete as appropriate. If no deletion is made, Hong Kong law shall apply.

The Model Arbitration Clause provides that English be used in arbitrations. However, arbitrations can also be conducted in Chinese. In fact, this is one of the advantages of having arbitrations in Hong Kong, especially when one or both of the parties are from Mainland China, Taiwan or Hong Kong and they speak Chinese only. In fact, parties from Hong Kong and Mainland China were the top two groups of people having arbitrations in the HKIAC. Moreover, there is a trend that Chinese is demanded by the parties in more arbitrations. In 2015, 79 per cent of the arbitration cases were conducted in English, 7.4 per cent in Chinese and 13.6 per cent in both English and Chinese and in 2016, 79.8 per cent in English, 12.8 per cent in Chinese and 7.5 per cent in both English and Chinese.

Another advantage is that Hong Kong or Chinese Law can be the governing law in arbitrations in Hong Kong. In fact, Hong Kong or Chinese Law was applied in many arbitration cases.

### 3.2 Arbitration agreement

According to Section 19 of the Ordinance by adopting Article 7 of the Model Law:

“Arbitration agreement” is an agreement by the parties to submit to arbitration all or certain disputes which have arisen or which may arise between them in respect of a defined legal relationship, whether contractual or not. An arbitration agreement may be in the form of an arbitration clause in a contract or in the form of a separate agreement.

It is a condition that an arbitration agreement must be in writing. However, the meaning of “writing” is very wide. An arbitration agreement is in writing if its content is recorded in any form, such as a written contract, an arbitration clause etc., and there is no need for the parties to sign such written document. It can also be in the electronic form, such as electronic data interchange, electronic mail, telegram, telex, etc. By reference to an arbitration agreement is also acceptable, such as a bill of lading to incorporate the arbitration clause in a charter party. See Sea Powerful II Special Maritime Enterprises (ENE) v. Bank of China Ltd ([2016] 1 HKLRD 1032) that the bill of lading incorporated the terms and conditions of a charter party, which in turn contained an arbitration clause. The Court of First Instance held that the Hong Kong court should grant an injunction to restrain the pursuit of foreign proceedings brought in breach of an agreement for Hong Kong arbitration.

### 3.3 Stay of proceedings

When an arbitration agreement is valid, a party is not allowed to commence legal proceedings to resolve the dispute. Otherwise the court proceedings will be stayed.

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<td>MA</td>
<td>106 (17%)</td>
<td>191 (38%)</td>
<td>173 (38%)</td>
<td>51 (11%)</td>
<td>74 (15.5%)</td>
<td>94 (18%)</td>
<td>99 (21.6%)</td>
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**Source:** From the website of HKIAC

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**Table II.** The number and percentage of maritime arbitration cases between 2010 and 2016
In *William Company v. Chu Kong Agency Co Ltd* ([1995] 2 HKLR 139), the plaintiff instituted proceedings in Hong Kong to recover damages for cargo damage on a vessel under a bill of lading issued by the defendants. The bill of lading contained a clause providing that all disputes to be resolved in the courts of the People’s Republic of China or by the arbitration in China. The defendants applied for a stay in favour of the arbitration in China. The court held that the word “may” in the dispute resolution clause gave the right of choice for arbitration or litigation in China to the plaintiff. As the plaintiff had opted for a method not agreed by the parties, it was opened to the defendants to exercise their choice by applying for a stay. Thus, the stay of proceedings was granted. The said rule applies even if the arbitration is in relation to a claim under the Employees’ Compensation Ordinance. In *Paquito Lima Buton v. Rainbow Joy Shipping Ltd Inc* ([2007] 1 HKLRD 926), the employee brought an action against his employer for personal injury. However, there was an international arbitration agreement in the employment contract. The employer thus applied for a stay of the proceedings in favour of the arbitration. The judge of the District Court decided that the claim was not arbitrable because the District Court had exclusive jurisdiction over the statutory employees’ compensation. On appeal by the employer, the Court of Appeal ordered for the proceedings to be stayed and the injury claim be referred to the arbitration.

### 3.4 Institutional and ad hoc arbitration

Maritime arbitration can be conducted in the form of an institutional or an *ad hoc* arbitration. Institutional arbitration refers to the arbitrations conducted in accordance with the rules and procedures of an arbitration institution. Examples of arbitral institutions include:

- the HKIAC;
- the London Maritime Arbitrators Association (LMAA);
- the ICC based in Paris; and
- the China Maritime Arbitration Commission (CMAC), which set up its Hong Kong Arbitration Centre in November 2014 after the China International Economic and Trade Arbitration Commission also established its arbitration centre in Hong Kong in 2012.

Most *ad hoc* arbitrations, however, follow no rules and they are up to the parties to agree on the procedures to follow, without referring to any arbitral institution. They can be divided into two categories: the document-only arbitration and the oral hearing arbitration. The document-only arbitration is generally cheaper and faster and is usually suited to small claims or where there is a single issue at stake.

### 3.5 Composition of arbitral tribunal

The parties have the freedom to decide the composition of the arbitral tribunal to be formed by one, two or three arbitrators (S 23, AO). If the parties fail to agree on the number of arbitrators, the right to decide the number of arbitrators is delegated to the HKIAC to have either one or three arbitrators.

An arbitration agreement may agree that an arbitrator should be “a commercial shipping man”. The meaning of a “commercial shipping man” was provided in *Vincor Shipping Co Ltd v. Transatlantic Schiffsahrtskontor GmbH* ([1987] HKLR 613). In an arbitration, the appointee was qualified as a solicitor in 1970 and practiced in London.
for three years handling cargo claims, charter party disputes and personal injury claims. In 1973, he joined the London correspondents of a P and I Club. In 1979, he acted as the Hong Kong correspondent of a P and I Club. He started up on his own in 1984 as the correspondent for two P and I Clubs handling marine claims and charter party disputes. He had also acted as an arbitrator in shipping disputes. The court decided that the appointment of a “commercial shipping man” should be given a sensible construction and should have open the possibility of arbitrators being chosen from a wide field of persons with commercial experience so long as they were not practicing lawyers. As the appointee was engaged full-time in commercial shipping, he was a commercial shipping man qualified to be an arbitrator.

3.6 Interim measures
By the adoption of the Model Law, one of the important changes is the additional provisions regarding interim measures. Section 35 of the ordinance provides that “the arbitral tribunal may, at the request of a party, grant interim measures”. The interim measures are temporary measures made prior to the issuance of an award. They include injunctive relief, to maintain or restore the status quo, to prevent harm or prejudice to the arbitral process, to preserve assets and evidence. Additionally, arbitral tribunals are empowered to order the provision of security for costs and direct the discovery of documents or delivery of interrogatories (Article 17, the Model Law).

Moreover, according to Section 45 of the ordinance, Hong Kong courts are empowered to grant interim relief in protection of arbitrations which are yet to be commenced outside Hong Kong. In the case of CSSC Huangpu Wenchong Shipbuilding Co Ltd v. Dry Bulk Services Ltd ([2016] HKCFI 2162), the judge agreed to freeze $13.7m in assets belonging to a Hong Kong ship management company during two ongoing London arbitrations. It was because the plain tiff shipbuilding company claimed against the defendant management company for overdue scheduled payments and had “a good arguable case”.

3.7 Effect and enforcement of awards
An award made by an arbitral tribunal is final and binding on both parties (Section 73, AO).

The ordinance does not adopt the enforcement provisions of the Model Law. Section 84 of the ordinance provides that, with the leave of the court, an award, whether made inside or outside Hong Kong, is enforceable in the same manner as a court judgment.

As there is an extremely close relationship between Hong Kong and Mainland China, the Department of Justice in Hong Kong and the Supreme People’s Court in China reached the Arrangement Concerning Mutual Enforcement of Arbitral Awards between the Mainland and Hong Kong (the “Arrangement”) in 1999 basing on Article 95 of the Basic Law. This is an important development in judicial assistance between the two jurisdictions and implementation of the “one country, two systems” principle (Zhang, 1999).

Under the reciprocity principle, courts in Hong Kong agree to enforce awards made pursuant to the Chinese Arbitration Law (Section 92, AO) and the People’s Courts also agree to enforce awards made pursuant to the Arbitration Ordinance in Hong Kong (Preamble of the Arrangement). Article 1 of the Arrangement provides that:

Where a party fails to comply with an arbitral award, whether made in Mainland or in the HKSAR, the other party may apply to the relevant court in the place where the party against whom the application is filed is domiciled or in the place where the property of the said party is situated to enforce the award.
The meaning of “the relevant court” is the Court of First Instance in Hong Kong and the Intermediate People’s Court in China (Article 2, the Arrangement). For enforcement of an award, the applicant has to submit to the relevant court an application for enforcement together with the arbitral award and the arbitration agreement (Article 3, the Arrangement and Section 94, AO).

From 1999 to 2011, more than 90 arbitral awards made in Mainland China were recognised and enforced in Hong Kong. On the other hand, between 2000 and 2008, at least 24 Hong Kong arbitral awards were executed in Mainland China (Gu and Zhang, 2012). According to a survey, people enforcing foreign arbitral awards in China might face some difficulties, but a large majority were fortunately able to recover all or most of their awards (Alford et al., 2016).

Other foreign awards are also enforceable in Hong Kong because Hong Kong has adopted the Convention on the Recognition and Enforcement of Foreign Arbitral Awards (New York Convention). New York Convention awards are recognised and can be enforced in Hong Kong either by action in the court or in the same manner as an arbitral award (Section 87, AO).

As arbitral awards made in Hong Kong can be enforced in China and in other countries by applying the New York Convention and vice versa, this arrangement can encourage more parties to have their disputes to be resolved in Hong Kong by the arbitration (Reyes, 2017).

4. Conclusion
Hong Kong has very good conditions in different aspects to make it one of the best maritime arbitration centres, especially in the Asia Pacific Region. As discussed, the legal system, the maritime experts, the languages, the international shipping centre and the support of the HKIAC have provided a solid foundation for international maritime arbitration in Hong Kong. By adopting the Model Law and the New York Convention in the arbitration law in Hong Kong, this unified legislative policy has further promoted the international maritime arbitration. Finally, Hong Kong being the door to the People’s Republic of China, it is advantageous that Mainland Chinese awards are recognised and enforced in Hong Kong and vice versa.

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Further reading

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Impact of Maritime Labour Convention on design of new ships

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Abstract

Purpose – The Maritime Labour Convention (MLC) embodies standards of existing international maritime labour conventions and recommendations, as well as the fundamental principles to be found in other international labour conventions. The aim of the convention is to address the employment standards of seafarers in the areas of fair wages, contractual terms, working and living conditions, as well as their health and safety on board ships. The purpose of this paper is to provide an in-depth study of MLC Regulation 3.1, specifically on the layout design of the accommodation spaces and possible solutions to meet the new demands as those will certainly affect the crew comfort, health and well-being on board ships.

Design/methodology/approach – The approach used includes a review of pre- and post-MLC conventions and regulations. This is then followed by looking at the impact of MLC Regulation 3.1 on new ship design. Possible solutions for new ship design are then proposed.

Findings – The findings from the paper were as follows: More flexibility in the form of non-mandatory guidelines and substantial equivalence under MLC. Under MLC, only Special Purpose Ship (SPS) is allowed to accommodate four persons in one room. The requirement for increased height and floor spaces would result in increased gross register tons (GT) for post-MLC built vessels. Impact due to post-MLC requirements would be more unfavourable for the design of smaller vessels below 500 GT than of bigger vessels of up to less than 3,000 GT. Possible solutions include applying for exemptions and substantial equivalents with flag states or registering with a non-ratifying flag state.

Originality/value – This paper has been based on a dissertation carried out for the partial fulfilment of a post-graduate degree. It has not been published in any journal.

Keywords Regulation, Convention, Accommodation, Labour, Maritime, MLC

Paper type General review

1. Introduction

The Maritime Labour Convention (MLC) is an instrument of the International Labour Organization (ILO) adopted on 23 February 2006 in Geneva, Switzerland. It embodies standards of existing international maritime labour conventions and recommendations, as well as the fundamental principles found in other international labour conventions (ILO, 2006).

The authors would like to acknowledge that it is not easy to find a convention that suits every country in the world and that the MLC is a comprehensive international framework in place which has addressed employment standards and social justice. However, the authors would like to recommend to the ILO to reconsider the floor areas for smaller vessels, especially those below 500 GT. The floor area requirements for these ships are the same as the floor space requirements for ships of up to less than 3,000 GT, and as such this has penalised the owners of smaller vessels that are below 500 GT.
According to the ILO, the purpose of MLC Regulation 3.1 is to ensure that seafarers have decent accommodation and recreational facilities on board that are consistent with promoting the seafarers’ health and well-being (ILO, 2006). It can be argued that MLC Regulation 3.1 could be indirectly linked to the safety of a ship as the environmentally catastrophic grounding of the Exxon Valdez in Alaska in 1989 might be due to the fatigue of the deck watch keeping officer on duty (Hetherington et al., 2006).

The aim of this paper is to provide an in-depth study of MLC Regulation 3.1, specifically on the layout design of the accommodation spaces, as this could affect the crew comfort and well-being on board. This paper is organised into five main sections: Introduction, Review of pre- and post-MLC, Impact of MLC Regulation 3.1, Possible Solutions and Conclusion.

2. Review of pre- and post-MLC
2.1 Background
The date of entry into force for the Member state is significant because under Paragraph 2 of MLC Regulation 3.1, the requirements in implementing are as follows:

This Regulation which relate to ship construction and equipment apply only to ships constructed on or after the date when MLC comes into force for the Member concerned. For ships constructed before that date, the requirements relating to ship construction and equipment that are set out in the Accommodation of Crews Convention (Revised), 1949 (No. 92), and the Accommodation of Crews (Supplementary Provisions) Convention, 1970 (No. 133), shall continue to apply to the extent that they were applicable, prior to that date, under the law or practice of the Member concerned. A ship shall be deemed to have been constructed on the date when its keel is laid or when it is at a similar stage of construction (ILO, 2006).

The dates of entry into force of the Member States differ other than the first 30 Member States to ratify the MLC; hence, for ease of comparison in this paper, 20 August 2013 is used as the MLC’s date of entry into force and any date before that would be considered as pre-MLC and any date after that as post-MLC. A ship with its keel laid post-MLC would be considered a “new ship” in this paper.

2.2 Accommodation of Crews Convention (Revised), 1949 (ILO No. 92)
ILO No. 92 was adopted by ILO on 18 June 1949 and entered into force on 29 January 1953 (ILO, 1949).

2.2.1 Applicability. The convention is applicable to every sea-going mechanically propelled vessel of 500 gross register tons (GT) or more that is not engaged in fishing, whaling or similar pursuits, and is registered in a territory for which the convention is in force. Under Article 2(g) of ILO No. 92, “the term crew accommodation includes such sleeping rooms, mess rooms, sanitary accommodation, hospital accommodation and recreation accommodation as are provided for the use of the crew” (ILO, 1949).

2.2.2 Summary of requirements.
(1) Requirements for sleeping rooms:
- Sleeping rooms should be situated above the load line amidships or aft. In exceptional cases such as in an offshore support vessel (OSV), they may be permitted to locate in the fore part of the ship, but in no case forward of the collision bulkhead.
- Sleeping rooms for passenger ships can be located below the load line, but not immediately beneath working alleyways.
Depending on the GT of the vessel, minimum floor area per person for ratings should be provided. Flag state may reduce the minimum floor areas if the ship is required to use a substantially large number of ratings than normal.

- The required clear head room in crew sleeping rooms should be at least 190 cm and the minimum inside dimensions of a berth must be at least 190 cm × 68 cm.

- There are requirements for the maximum number of persons that are allowed to occupy sleeping rooms based on their ranks such as officers in charge of a department, navigating and engineer officers in charge of a watch, senior radio officers and operators, petty officers and other ratings.

- Each occupant should be provided with a clothes locker with a minimum height of 152 cm (1.52 m) and cross-section area of 19.30 dm² (0.193 m²). This would be approximately 0.294 m³ (1.52 × 0.193) or 294 L. A drawer or equivalent space of minimum volume of 0.056 m³ or 56 L should also be provided.

2 Requirements for mess rooms:
- Depending on the GT, there are conditions for separate mess rooms for masters, officers, petty officers and other ranks, including persons in the catering department.
- Mess rooms should be located away from the sleeping rooms and as close as possible to the galley.

3 Requirements for sanitary accommodation:
- Depending on the GT, there are minimum numbers of required separate water closets.
- Other minimum sanitary facilities include tub or shower bath, and wash basins for all members of the crew who do not occupy rooms with attached private facilities.

4 Requirements for hospital accommodation:
- Any ship carrying a crew of 15 or more and engaged in a voyage of more than three days’ duration is required to have a separate hospital accommodation used for medical purposes only.
- Toilet facility for the exclusive use of the occupants of the hospital accommodation should be provided.
- The flag state will prescribe the number of hospital berths required and may relax the requirement for hospital accommodation for vessels engaged in coastal trade.

5 Requirements for recreation accommodation:
- Recreation facility should be conveniently situated and if in the mess room, should be furnished and equipped.

2.3 Accommodation of Crews (Supplementary Provisions) Convention, 1970 (ILO No. 133)
ILO No. 133 was adopted by ILO on 30 October 1970 to provide further improvements in crew accommodation and entered into force on 27 August 1991. Countries that ratify ILO No. 133 have also ratified and comply with the provisions of ILO No. 92 (ILO, 1970). The opposite does not apply if a country has only ratified ILO No. 92.

2.3.1 Applicability. The convention applies to every sea-going mechanically propelled vessel of 1,000 GT or more that is not engaged in fishing, whaling or similar pursuits; is not
a hydrofoil and air-cushion craft; and is registered in a territory for which the convention is

2.3.2 Summary of requirements

(1) General requirements for accommodation spaces:
- The minimum headroom in all crew accommodation should be at least 198 cm. It is 8 cm more than ILO No. 92.
- Flag state may permit limited headroom reduction if it is satisfied that the reduction is reasonable.

(2) Requirements for sleeping rooms:
- Depending on the GT, the minimum floor area per person for ratings should be provided, which is larger than that stated in ILO No. 92 for similar GT range. For example, in ships of 1,000 GT or over but less than 3,000 GT, the minimum floor area per person is 3.75 m² in ILO No. 133 compared to 2.35 m² for the same GT range in ILO No. 92. It is almost 60 per cent more.
- There is also a provision for sleeping rooms with two ratings; the minimum floor area per person for the same GT range is 2.75 m² in ILO No. 133 compared to 2.35 m² for the same GT range in ILO No. 92, and would be more applicable as ratings are seldom allocated an individual sleeping room.
- The number of ratings per sleeping room should not exceed two persons per room, except in passenger ships where the maximum number can be four.
- The number of petty officers occupying sleeping rooms should be one or two persons per room, and should not exceed two persons per room.
- For bigger ships of 3,000 GT or over, the chief engineer officer and the chief navigating officer should have, in addition to their sleeping room, an adjoining sitting room or day room. Although not clearly stated for the Master, it can be assumed that the Master would already have an adjoining living room or day room, in addition to his sleeping room.
- The minimum inside dimensions of a berth in ILO No. 133 should be 198 cm × 80 cm), which is bigger than the berth in ILO No. 92 (190 cm × 68 cm).

(3) Requirements for mess rooms:
- The minimum floor area of mess rooms for officers and for ratings is 1 m² per person of the planned seating capacity. There is no minimum floor area of mess rooms in ILO No. 92.

(4) Requirements for sanitary accommodation:
- Minimum of one water closet and one tub and/or shower bath for every six persons or less in ILO No. 133 as compared to every eight persons or less in ILO No. 92.
- Separate sanitary facilities if women are employed are stated in ILO No. 133, which is missing in ILO No. 92.
- Bigger ships of 5,000 GT and above should be provided with attached private bathrooms to the individual sleeping rooms of officers.

(5) Requirements for recreation accommodation:
- The requirements for recreation accommodation in ILO No. 133 are more detailed and include a minimum of bookcase and other facilities for reading, writing and, where practical, for games.
Ships of 8,000 GT and above should be provided with a smoking room or library room in which films or television may be shown as well as a hobby and games room.

There is even a consideration for the provision of a swimming pool and a canteen.

2.4 Post-MLC accommodation spaces (MLC regulation 3.1)

2.4.1 Applicability. MLC Regulation 3.1 applies to a new ship that is at least 200 GT only if it is a “ship other than one which navigates exclusively in inland waters or waters within, or closely adjacent to, sheltered waters or areas where port regulations apply” (ILO, 2006).

There was a question of whether MLC applies to offshore resource extraction such as Mobile Offshore Drilling Units (MODU) or vessels that are not self-propelled. According to the ILO, this will “depend on two factors: whether the vessel is considered a ship under the relevant national law and the location of its activities” (ILO, 2012). It shows the flexibility of ILO in allowing the flag state to decide if MLC applies to such ship types registered with it. It has resulted in countries such as Panama and Liberia declaring that MLC is not applicable to MODU (PMA, 2012; LMA, 2014). United Kingdom is, however, treating a self-propelled MODU as a ship and MLC will be applicable (MCA, 2013).

2.4.2 Flexibility. Besides the above example, according to the ILO, there are two main areas that allow a considerable degree of flexibility in the way a Member state implement the MLC: Non-Mandatory Part B and Substantial Equivalence.

2.4.2.1 Non-mandatory part B. The regulations and the provisions of Part A are mandatory, while the provisions of Part B are non-mandatory guidelines for implementation. The mandatory requirements of Part A are also formulated in a more general way, “thus leaving a wider scope for discretion as to the precise action to be provided for at the national level” (ILO, 2006).

2.4.2.2 Substantial equivalence. A “Member which is not in a position to implement the rights and principles in the manner set out in Part A of the Code may […] implement Part A through provisions in its laws and regulations or other measures which are substantially equivalent to the provisions of Part A”.

2.4.3 Summary of requirements

(1) General requirements for accommodation spaces:

- The minimum headroom in all seafarer accommodation should be at least 203 cm. It is 5 cm more than in ILO No. 133 and 13 cm more than in ILO No. 92. However, again there is a provision for the flag state to permit limited reduction if it is satisfied that the reduction is reasonable.

- Similar to ILO No. 92, there is a requirement for sleeping rooms to be situated above the load line amidships or aft, except that in exceptional cases, sleeping rooms may be located in the fore part of the ship, but not forward of the collision bulkhead.

- For passenger ships, and in ships constructed in compliance with the IMO Code of Safety for Special Purpose Ships (SPS Code), the flag state may permit the location of sleeping rooms below the load line, but they cannot be located immediately beneath working alleyways.

(2) General non-mandatory guidelines for accommodation

- Some of ILO No. 92 requirements are found in the non-mandatory MLC guidelines for accommodation. Examples are adequate insulation from heat,
and materials used for bulkhead and deck head construction should not
harbour vermin.

(3) Requirements for sleeping rooms:
- Depending on the GT, minimum floor areas in single berth seafarers’ sleeping
rooms are to be provided. These minimum floor areas are bigger than those
stated in ILO No. 133 for similar GT range. For example, in ships of less than
3,000 GT, the minimum floor area per seafarer is 4.5 m² in MLC 2006, as
compared to 3.75 m² for the same GT range in ILO No. 133.
- For sleeping rooms with two seafarers, the minimum floor area for the same GT
range is 7 m² or 3.5 m² per seafarer as compared to 2.75 m² in ILO No. 133.
Similar to ILO No. 133, there are provisions for flag state to allow a reduced floor
area on ships of less than 3,000 GT, passenger ships and special purpose ships.
- Each occupant should be provided with a clothes locker with a minimum of
475 L and a drawer or equivalent space of not less than 56 L. This clothes
locker is more than 60 per cent bigger than the clothes locker (294 L) required
in ILO No. 92.

(4) Non-mandatory guidelines for sleeping rooms:
- Some of ILO No. 92 requirements are found in the non-mandatory MLC
guidelines for accommodation. An example is that space occupied by berths
and lockers, chests of drawers and seats should be included in the
measurement of the floor area.

(5) Requirements for mess rooms:
- The requirements for mess rooms in MLC are very general such as mess rooms
have to be located apart from the sleeping rooms and as close as practicable to the
galley. There is no minimum floor area unlike ILO No. 133 that has a minimum
requirement of 1 m² per person of the planned seating capacity.

(6) Non-mandatory guidelines for mess rooms:
- An example of ILO No. 92 requirements found in the non-mandatory MLC
guidelines for mess rooms is the separate mess rooms for master and officers
as well as petty officers and other seafarers.
- There is also a non-mandatory guideline for a minimum floor area of 1.5 m²
per person of the planned seating capacity as compared to a minimum
requirement of 1 m² per person in ILO No. 133.

(7) Requirements for sanitary facilities:
- Similar to ILO No. 133, there is a requirement in MLC for a minimum of one
toilet and one tub and/or shower bath for every six persons or less.

(8) Non-mandatory guidelines for sanitary facilities:
- Some examples of ILO No. 92 requirements found in the non-mandatory MLC
guidelines for sanitary facilities are bulkheads should be of steel or other
approved material and should be watertight up to at least 23 cm above the
level of the deck.
- An ILO No. 133 requirement for laundry facilities is also found in the non-
mandatory MLC guidelines for sanitary facilities.

(9) Requirements for hospital accommodation:
- The MLC requirement for hospital accommodation is similar to the
requirement found in ILO No. 92.
Non-mandatory guidelines for hospital accommodation:

- ILO No. 92 requirements as discussed in Section 2.2.2 d of this article are found in the non-mandatory MLC guidelines for hospital accommodation. An example is a sanitary facility for hospital accommodation.

Requirements for recreational facilities:

- The MLC requirements for recreational facilities are general and non-specific.

Non-mandatory guidelines for recreational facilities:

- Some examples of ILO No. 133 requirements found in the non-mandatory MLC guidelines for recreational facilities are that furnishings for recreational facilities should as a minimum include a bookcase and facilities for reading, writing and, where practical, games.

3. Impact of MLC regulation 3.1 on new ship design

3.1 Principal dimensions of new ship

According to MLC Standard A3.16(a), the minimum permitted headroom in all seafarer accommodation shall not be less than 203 cm. This MLC requirement is 5 cm more than that in ILO No. 133 and 13 cm more than that in ILO No. 92. Depending on the location of the crew accommodation, this could result in either an increased height of the deckhouse and/or depth of a post-MLC vessel to meet this requirement.

However, there is also a degree of flexibility for this requirement of 203 cm headroom under the same MLC standard, as “a competent authority may permit some limited reduction in headroom in any space, or part of any space, in such accommodation where it is satisfied that such reduction:

- is reasonable; and
- will not result in discomfort to the seafarers (ILO, 2006).

The requirements for increased floor spaces such as MLC Standards A3.19(f), (h), (i), etc. could either result in increased length and/or breadth of a post-MLC vessel or reduced commercial capacities such as cargo or passengers. According to the Regulatory Policy Committee (RPC) of the United Kingdom in its impact assessment of the MLC, the preferred approach would vary depending on the type of new ship built (RPC, 2014).

Should owners decide to order larger ships regarding length, breadth, depth and/or bigger deckhouses to meet the above MLC requirements without sacrificing commercial capacities, then the GT of such ships would increase. According to Regulation 3 of the International Convention on Tonnage Measurement of Ships, 1969 (TM 69) of IMO, the GT of a ship shall be determined by the following formula (IMO, 1969):

$$ GT = K_1 V $$

where $V = \text{Total volume of all enclosed spaces of the ship in cubic metres}$; and

$$ K_1 = 0.2 + 0.02 \log_{10} V. $$

$K_1$ is the multiplier based on ship’s volume and its value can also be obtained by linear interpolation using the values tabulated in Appendix 2 of the TM69 Convention.

Enclosed spaces are defined under Regulation 2 of the TM69 Convention as follows:

[... all those spaces which are bounded by the ship's hull, by fixed or portable partitions or bulkheads, by decks or coverings other than permanent or movable awnings. No break in a deck, nor any opening in the ship's hull, in a deck or in a covering of a space, or in the partitions or
bulkheads of a space, nor the absence of a partition or bulkhead, shall preclude a space from being included in the enclosed space (IMO, 1969).

3.2 On the design of smaller vessels below 500 GT
MLC applies to smaller vessels such as 200 GT onwards that go on international voyages compared to ILO No. 92 (vessels of 500 GT and above) and ILO No. 133 (vessels of 1,000 GT and above).

A study conducted on a 247 GT ocean going tug built pre-MLC shows that such a vessel can accommodate up to 12 seafarers with two single-berth cabins, three double-berth cabins and one four-berth cabin. Prior to MLC, this vessel does not even need to comply with ILO No. 92.

If a sister vessel were to be built post-MLC, even if the floor areas of the sleeping rooms are able to meet the requirements of MLC, the four-men sleeping room will not be able to comply. This is because under MLC Standard A3.1.9(h), sleeping rooms in ships of less than 3,000 GT other than passenger ships and special purpose ships may be occupied by a maximum of only two seafarers.

Another non-compliance is that under MLC Standard A3.1.9(k), it can be inferred that each seafarer performing the duties of ships’ officers is to be provided with a single-berth cabin. Assuming that there are only three officers (Master, Chief Engineer Officer and Chief Navigating Officer) in the minimum safe manning requirement for such a vessel, there will be a shortage of one single-berth cabin.

Without increasing the vessel’s dimensions to allow for the addition of cabins and assuming that the floor areas of all the sleeping rooms are sufficient for MLC, the four-men sleeping room could be redesigned as a two-men sleeping room, and one of the two-men sleeping rooms could be redesigned as a single-berth sleeping room. However, this means that the vessel can now only accommodate nine seafarers instead of 12 and may not be able to meet the minimum safe manning requirements of the flag state it is registered with.

3.3 Design of offshore support vessels that are non-SPS and below 3,000 GT
The 2008 SPS Code was developed by the IMO for specialised types of ships that may have an unusual design and operational characteristics, which differ from those of conventional merchant ships such as passenger ships. Such specialised vessels are also likely to carry more than 12 special personnel, who are neither crew members nor passengers as defined in the SOLAS Convention (IMO, 2008) and are not able to comply with the SOLAS requirements for passenger ships. However, as the code is voluntary, there are pre-MLC built vessels that have accommodation for more than 12 special personnel, but are not SPS Code compliant.

A study on the crew accommodation spaces of a 1671 GT Subsea Support Vessel built pre-MLC shows that the vessel can accommodate up to 50 persons with four single-berth cabins, five double-berth cabins and nine four-berth cabins. The ship designer has designed the accommodation for 14 crew and 36 special personnel. Assuming that the vessel is non-SPS Code compliant, then such a vessel if it were to be built post-MLC would not be able to meet both MLC Standards A3.1.9(h) and A3.1.9(j) requirements. To comply with the abovementioned MLC requirements for a post-MLC sister vessel and assuming that the floor areas of all the sleeping rooms are sufficient for MLC, such a vessel would need to comply with the SPS Code. Once it can obtain the class notation of SPS, then there won’t be a need to make changes to the layout design of the accommodation spaces.
3.4 Design of large passenger ships

According to the RPC of the United Kingdom in its impact assessment of the MLC, indications from United Kingdom’s passenger cruise ship industry are that companies would order ships of the same size and take additional space needed for crew accommodation from existing passenger space. The main reason for choosing this approach would be restrictions on the ports as passenger ships are mainly constrained by the ports they visit in terms of draught and beam when entering the harbour and air draft when passing under certain bridges. This is also because an increase in height has significant stability implications for the vessel. In addition, the passenger facilities that are available on board cruise ships are considered to be an essential part of the service, suggesting that passenger accommodation space in terms of the number of cabins would likely reduce (RPC, 2014).

3.5 Design of other types of ships 3,000 GT and above

The findings received by RPC from industry sources have shown that the impact of MLC Regulation 3.1 on container, bulk carriers and tankers is assumed to be insignificant. These classes of ship generally have a small enough crew and sufficient flexible space that the additional accommodation space could be included without increasing the overall size of the ship (RPC, 2014).

4. Possible solutions for new ship design

4.1 Applying for exemptions with flag states

According to ILO, it is possible for the ratifying flag states to grant exemptions but to a limited extent and only where they are expressly permitted by the MLC (ILO, 2006). An example is MLC Standard A3.1.9(a) which states the following:

[...] in ships other than passenger ships, an individual sleeping room shall be provided for each seafarer; in the case of ships of less than 3,000 gross tonnage or special purpose ships, exemptions from this requirement may be granted by the competent authority after consultation with the ship owners’ and seafarers’ organizations concerned.

To explore the option of applying for exemption as a possible solution, the maritime regulations of three flag states related to MLC Regulation 3.1 were examined. According to the 2012 United Nations Conference on Trade and Development (UNCTAD) Review of Maritime Transport Publication, the World’s top three flags of registration with the largest registered deadweight tonnage are Panama, Liberia and Marshall Islands, respectively with a combined 41.78 per cent share of the World’s total deadweight tonnage (UNCTAD, 2012). These three flag states are also among the first 30 Member States that had ratified the MLC and are considered open registries, i.e. they have no restriction on the nationality of the ship owners registering ships with their flags.

4.1.1 Panama. Under Article 154 of the Executive Decree No. 86 issued by the Ministry of the Presidency of the Republic of Panama (PMA, 2013), the competent authority shall authorise exemptions from the requirements contained in Title Fourth of the decree, which is related to accommodation, and only with regards to special circumstances as long as each of the following conditions is fulfilled:

- The exemption is expressly authorised by this Executive Decree.
- The exemption is reasonable, taking into account the size of the ship and the number of persons aboard.
- The exemption can clearly be justified and supported by valid reasons.
The exemption is granted subject to the safety and health of seafarers being protected.

The exemptions that are expressly authorised by decree are similar to the ones that are expressly permitted by the MLC, such as the MLC Standard A3.1.9(a) mentioned earlier.

4.1.2 Liberia. According to the Marine Notice MLC-004 issued by the Liberia Maritime Authority (LMA, 2013), any exemptions permitted by the administration for the requirements of accommodation and recreational facilities stated in the marine notice shall only be granted by the administration for particular circumstances in which such exemptions can clearly be justified on substantial grounds and subject to protecting the seafarers’ health and safety. As the requirements and exemptions of accommodation and recreational facilities in the above marine notice are similar to those stated in MLC Regulation 3.1, there is no indication of whether other exemptions may be allowed. It could perhaps be answered when a ship owner has submitted an application with the flag administration.

4.1.3 Marshall Islands. According to the Marine Notice No. 7-044-1 issued by the Office of the Maritime Administrator of the Republic of Marshall Islands (RMI, 2014), for ships of less than 3,000 gross tons, where it is reasonable to do so, in relation to the requirements of the provisions specified below and considering the size of the ship and the number of persons on board, ship owners may seek exemption under MLC 2006 Title 3 from the Administrator from compliance with:
- MLC Standards A3.1.9(f), (h), (i), (j), (k) and (l) with respect to floor area only; and
- MLC Standards A3.1.9(m) and (n)

The equivalent arrangements for ships noted above may also be considered. Any exemptions with respect to the requirements of the minimum standards in the marine notice may be made only where they are expressly permitted in the minimum standards and only for particular circumstances in which such exemptions can clearly be justified on strong grounds and subject to protecting the seafarers’ health and safety.

In comparison with the other two flags, it may seem that the Marshall Islands flag administration is more inclined to allow exemptions. However, the question of what exactly can be exempted or perhaps be reduced in floor areas, for example, would be best answered by communicating with the flag administrations. Besides the above three flags, there are other open registries, which a ship owner can also consider and which may interpret the MLC requirements and exemptions differently. Another option for a ship owner to consider is to apply for substantial equivalents with the flag state.

4.2 Applying for substantial equivalents with the flag states
Under Paragraph 3 of MLC Article VI, a “Member which is not in a position to implement the rights and principles in the manner set out in Part A of the Code may [...] implement Part A through provisions in its laws and regulations or other measures which are substantially equivalent to the provisions of Part A”.

This is reinforced under Paragraph 4 of the same MLC article, which states that “for the sole purpose of Paragraph 3 of this Article, any law, regulation, collective agreement or other implementing measure shall be considered to be substantially equivalent, in the context of this Convention, if the Member satisfies itself that:
The answer to what can be considered a substantially equivalent provision can be found in the ILO's Frequently Asked Questions (FAQ) on MLC. An example is a question on “could less space be provided in sleeping accommodation in return for greater comfort?” One of the solid equivalent solutions suggested consists of extra space such as a big, more comfortable day room to be shared by adjoining sleeping rooms. Another proposed solution was the provision of ensuite sanitary facilities (ILO, 2012).

A real example of a substantially equivalent provision given by a flag state, which is publicly made known is found in the Marine Guidance Note (MGN) 517 (M) published by the Marine and Coastguard Agency (MCA) of the United Kingdom (MCA, 2014). This is for the substantially equivalent accommodation standards for large commercial yachts of 3,000 GT to less than 5,000 GT. After the publication of Large Commercial Yacht Code (LY3), which included provisions for MLC and permitted yachts of 3,000 GT and over to be built under the code for the first time, designers and builders raised concerns with the MCA that strict compliance with the LY3 standards may not create the best sleeping accommodation standards for seafarers on yachts of that size. The UK Government then consulted with its social partners on substantially equivalent accommodation standards for yachts of 3,000 GT to less than 5,000 GT and following the consultation, agreed to accept the alternative arrangements allowing two seafarers not performing the duties of officers to be accommodated in a twin cabin arrangement on the condition that the minimum floor area for such a cabin to be no less than 11 m². Prior to this substantial equivalent provision, under MLC Standard A3.1.9(h), sleeping rooms in ships of only less than 3,000 GT, other than passenger ships and special purpose ships, may be occupied by a maximum of two seafarers.

4.3 Registering the vessel with a non-ratifying flag state

Although this option may seem an unethical choice as it may appear to be avoiding compliance, it could be considered as a last resort. It is on assumption that the ship designer has not designed the ship to comply fully with MLC Regulation 3.1. Such a scenario could be more likely to happen to designers and builders of smaller vessels (below 500 GT) and at the time of designing or building the ship, they may not be aware of the requirements of MLC. Those vessels are operating in a country which has yet to ratify MLC, even though MLC has already been in force since 20 August 2013. There are still a considerable number of flag states that have not ratified MLC, even though some of them may be in the process of doing so. However, it can also be assumed that some of these flag states may also not be ratifying the MLC anytime soon as the ratification process for them will take a long time owing to various factors.

Non-ratifying flag states may advise the owners of the ships registered under their flags to comply voluntarily with MLC, but they will not be able to legally enforce the compliance as they have not acceded to MLC and adopt it into their legislation. A ship owner that registers a “new ship” with a non-ratifying flag state will run the risk of the vessel being inspected and detained at a port of a ratifying country if the ship is non-compliant because of the “no more favourable treatment clause” in Article V of MLC that seeks to ensure a level playing field for ships registered with flag states that have ratified MLC compared to those ships registered with flag states that haven’t ratified. Hence, this option should only be
considered for a new ship if it is only going to trade to ports of non-ratifying countries. However, this list of countries would also become smaller as more countries ratify MLC.

5. Conclusions and recommendations
Based on the study carried out in this article, the following can be concluded:

- There seems to be more flexibility in the form of non-mandatory guidelines and substantial equivalence for flag states under MLC compared to ILO No. 92 and No. 133, and such flexibility is also more specific.
- Some of the mandatory requirements of ILO No. 92 and No. 133 are found under the non-mandatory guidelines of MLC, thus allowing flag states that did not ratify these two pre-MLC conventions the flexibility of adopting or not adopting them under their legislation.
- Under MLC, only SPS is allowed to accommodate four persons in one room. It would have an adverse impact on offshore support vessels that are below 3,000 GT and not classed as SPS, as a similar type of vessels built pre-MLC and not classed as SPS could accommodate four seafarers in one room.
- The requirement for increased height and floor spaces under MLC would be more likely to result in increased principal dimensions (length, breadth and depth) rather than a reduction in commercial capacity, thereby resulting in increased GT for post-MLC built vessels compared to similar type of pre-MLC built vessels.
- Impact due to post-MLC accommodation spaces requirements on the design of smaller vessels below 500 GT would be more unfavourable compared to bigger vessels of less than 3,000 GT. It is because of the limitations of space available on smaller vessels of less than 500 GT and also the similar floor area requirements for ships of less than 3,000 GT.
- Possible solutions for new ship design to meet post-MLC accommodation spaces requirements include applying for exemptions and substantial equivalents with flag states or registering with a non-ratifying flag state.

References


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Assessing the shipping in the Northern Sea Route: a qualitative approach

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Abstract

Purpose – The Northern Sea Route (NSR) could become viable in the near future. If this happens, it will radically reduce sailing times and distances on routes from Asia to Northern Europe. However, although much has been written about the feasibility of the NSR, about the issues involved and about the possible opening of the route, the views of key stakeholders from companies who would potentially benefit from the route have been little explored. The purpose of this paper is to complement the existing literature on the feasibility of and issues related to the NSR by presenting and discussing the results from in-depth qualitative interviews with nine key stakeholders based in Shanghai and Taiwan who have extensive research, knowledge and practical experience of NSR.

Design/methodology/approach – Based on a grounded theory analysis, a total of nine key stakeholders knowledgeable about NSR and the majority with sailing experience of NSR are interviewed, including one government official, two professors, shipping experts in six liner and one bulk shipping companies.

Findings – The authors present interviewees’ thoughts regarding the feasibility of NSR at the current time in terms of practicalities, ships, costs, information and wider issues.

Practical implications – These thoughts show that whilst the potential of NSR is huge in theory, in practice the overall perception of it in terms of current feasibility from a company perspective is one of challenges and unknown issues. Shipping companies can benefit from the authors findings when considering the feasibility of NSR as a shipping route. Ultimately, the picture emerges that without one country, probably Russia, taking the lead on the route, it will remain only a theoretical one.

Originality/value – In-depth interviews with grounded theory are used to investigate current and actual thoughts on NSR. This paper highlights correlations and additions to show a fuller picture of current knowledge and adds views from Shanghai and Taiwan.

Keywords Grounded theory, Interview, Shipping, Northern Sea Route

Paper type Research paper

1. Introduction: potential and possibility of North Sea Route

Maritime routes linking Asia and Europe and North America have become the principal axes of container transport (Verny and Grigentin, 2009, p. 109). Based on UNCTAD
statistics, vessel port calls in Asia and Europe accounted for 80.2 per cent of global vessel port calls in 2015, and this has greatly increased recently (UNCTAD, 2016).

Much traffic now leaves from Northern China (Verny and Grigentin, 2009) with seven Chinese ports now in the world’s top ten container terminals[1]. Of Northern Polar routes between North America, Europe and Asia, three principal ones are the transpolar route (TSR), the Northwest Passage (NWP) through the Canadian Arctic and the Northern Sea Route (NSR) along the Russian coast (Hong, 2012). TSR is the riskiest, running through the middle of the Arctic Ocean (Humpert and Raspotnik, 2012), whereas NWP and NSR are coastally based. NWP connects the Atlantic and Pacific Oceans along the northern coast of North America via the Canadian Arctic Archipelago. NSR connects the Atlantic Ocean to the Pacific Ocean along the Russian coast of Siberia, via mostly Russian Arctic waters. In this paper, we focus on NSR, given its relation to trade between Europe and far East Asian ports such as Yokohama and Busan but also including Shanghai and Kaohsiung (see Figure 1) and draw on data from in-depth interviews with stakeholders working in ports that would use NSR. Both Shanghai and Kaohsiung are ports with significant amounts of trade. According to the World Shipping Council (2017), Shanghai’s volume of trade by million

<table>
<thead>
<tr>
<th>Sailing Route</th>
<th>Traditional Route (Nm)</th>
<th>NSR Route Estimates (Nm)</th>
</tr>
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<tbody>
<tr>
<td>Yokohama→Rotterdam</td>
<td>13,067</td>
<td>4,633</td>
</tr>
<tr>
<td>Busan→Rotterdam</td>
<td>12,515</td>
<td>5,185</td>
</tr>
<tr>
<td>Shanghai→Rotterdam</td>
<td>11,998</td>
<td>5,702</td>
</tr>
<tr>
<td>Kaohsiung→Rotterdam</td>
<td>11,434</td>
<td>6,266</td>
</tr>
</tbody>
</table>

**Source:** Map adapted from Google Maps and figure estimates based on Hong (2012)
TEU was the highest in the world at 36.54 in 2015, and Kaohsiung’s was ranked 13th at 10.26 million TEU. What is more, although the trade route between Asia to North America occupied the largest amount of cross-trade at 23,125,000 million TEU in 2013, the trade route between Asia and North Europe was ranked a clear second place with 13,706,000 million TEU (World Shipping Council, 2017). Our stakeholders were experts with much experience of sailing NSR and were based in Shanghai and Kaohsiung and ports in Taiwan (see section 3). They were thus fully aware of the possible significance of the opening up of NSR, and they had considerable experience of it in relation to the possibilities it would afford in terms of trade for the ports of Shanghai and Kaohsiung shown in Figure 1.

Regarding potential benefits, compared to the Suez Canal, NSR could cut 40 per cent (Liu and Kronbak, 2010; Lindstad et al., 2016), or approximately seven days, off journeys between Yokohama and Rotterdam. According to Hong (2012), this represents a reduction from 11,200 to 6,500 nautical miles, although according to other distance calculators, Yokohama to Rotterdam is a greater 13,067 nautical miles (Ports, 2017), which would in theory make the gains even greater for sailing NSR, by our estimations meaning this distance was only 4633Nm (6,500 minus the difference of 1867 between 11,200 (Hong, 2012) and 13,067 (Ports, 2017)). The Ports (2017) distance calculator calculates the distance from the major ports of Shanghai and Kaohsiung as slightly less but nevertheless similar as 11,998Nm and 11,434Nm, respectively (ibid). Whatever the precise distance, it is clear that sailing from these ports through NSR would represent huge reductions in the amount of nautical miles required for sailing, and the route is rightly described as being one which “will connect East Asia (Japan, South Korea, Taiwan and China) with Northwestern Europe through the Arctic Ocean” (Bekkers et al., 2016, p.2). We estimate these differences in the table accompanying Figure 1 above. Such distance reductions would save fuel, reduce emissions (DNV, 2010; Furuichi and Otsuka, 2013) and save time (Schøyen and Bråthen, 2011), making it twice as energy efficient (Schøyen and Bråthen, 2011) and a significant business opportunity for many countries (e.g. South Korea (Bennett, 2014)). In 2017, a Russian tanker carried a cargo of liquefied natural gas (LNG) from Hammerfest in Norway to Boryeong in South Korea in 19 days. It is estimated that it saved about 30 per cent time than the conventional southern shipping route through the Suez Canal (Guardian, 2017)[2].

Furthermore, combining NSR with other routes could increase annual shipping capacity (Furuichi and Otsuka, 2013), which is a highly appealing prospect given that pressure on the Suez canal means it may soon reach capacity (Drewry, 2008; Verry and Grigentin, 2009, p.109). Also, in recent years, China, Japan and Korea have successfully navigated the NSR (Stokke, 2013), and literature has commented on its potential for China (Hong, 2012), Korea (Bennett, 2014) and also Japan (Usami et al., 2016).

Nevertheless, there are many issues with NSR: sea ice and higher hazard levels (Laulajainen, 2009; Liu and Kronbak, 2010; Hong, 2012); higher risk of a reduced service (Hong, 2012); greater navigational needs (Liu and Kronbak, 2010); higher unit costs per distance travelled, given the need for ice strengthening and ice breaker support (Liu and Kronbak, 2010; Hong, 2012); higher ship building costs (Liu and Kronbak, 2010); and possible environmental impacts of oil spillage and increased air pollution (Schøyen and Bråthen, 2011). Crew training, protection of the cargo, the maintenance of both hulls and ship equipment are also extra concerns (Lee and Kim, 2015). In addition, navigating around sea ice means exact arrival times cannot be given, (Schøyen and Bråthen, 2011), which could represent an issue for shipping. Although recent aggregate time performance figures show that the liner shipping industry does not require perfect on time schedules, with some performances below 80 per cent (Port Technology, 2015), there is nevertheless a desire for greater reliability. In addition, container cargoes often require faster delivery times than
bulk cargo and such timing issues may be more important to them. Further, ship owners will be faced with managerial difficulties in route rescheduling and also losses from ships travelling far less (Laulajainen, 2009), and the draft of ships may be limited in NSR (Schøyen and Bråthen, 2011), thus reducing possible TEU equivalents.

Of fundamental importance to any company’s decision to use NSR is the fact that actually ascertaining what is known about NSR is highly complex. Assessment and quantifications of supply chain transport risks (Schøyen and Bråthen, 2011) are difficult, as is ascertaining when ice-free sailing will be possible (Lajeunesse, 2012). Further research is often called for (Furuichi and Otsuka, 2013), and some highlight a number of issues to address before NSR becomes feasible: establishing a polar code; improving Search and Rescue (SAR) services; improving infrastructure; political and legal agreements over tolls and permissions (Hong, 2012; Lee and Kim, 2015).

One continent that would use NSR should it become navigable is Asia. Asian shipping companies represent a huge proportion of the trade that uses traditional routes and would potentially benefit greatly from an NSR route through the reduced shipping times and savings it would potentially offer on routes to Europe. Yet, little research to date has studied what they think and almost none has adopted qualitative approaches. Some research has used surveys (Beveridge et al., 2016) and found that at the moment such a route is not one that Asian companies would consider. In this paper, we complement such research by presenting and discussing findings from an in-depth qualitative study with key stakeholders involved in shipping in Asia from Shanghai and Taiwan. We present their views regarding the current potential of NSR and their thoughts on the feasibility of it. Qualitative approaches are often used by companies to test products at a user-interface level (Bosch-Sijtsema and Bosch, 2015) after they have been quantitatively explored, and those are often used in logistics as initial studies before more in-depth quantitative or semi-quantitative studies are used (American Institute of Chemical Engineers, 1995). Here, our purpose in using qualitative approaches is to provide a complementary in-depth perspective alongside existing survey research and in addition to test current thinking with a view to comparing it to the extant literature.

The remainder of our paper is structured as follows. We first review some of the key literature in the field. We then detail our methodology and approach to gathering key stakeholder perspectives regarding current thinking on NSR from nine experts on NSR, six of whom have sailing experience of NSR. Following this, we discuss these in light of the literature before drawing together the main points in the conclusion.

2. Literature review
This literature review is divided into: technical issues, ships, costs, information and other issues. We stress at the outset that although we deal with these areas discretely, we recognise that there is substantial overlap and interrelation. Consequently, in a final section, we summarise the main points from the literature to bring the points together clearly.

2.1 Technical issues
By technical issues we mean issues that can affect the practical sailing of NSR. One practical issue relates to infrastructure. Although some literature notes past Soviet development of ports along the Siberian coast, much notes the inadequacy of this infrastructure regarding practical facilities or SAR for ships encountering pressured ice (Mussells et al., 2017), growler ice or other problems (Verny and Grigentin, 2009). Such ice and problems may continue many years into the future (Renfrow, 2006; Lajeunesse, 2012) and forecasting for aspects such as growler ice and ice sheet movements are fundamental to making NSR
feasible (Hong, 2012; Ho, 2010) as is recovering any oil spills (Hong, 2012). However, SAR and navigation technology is highly costly (Laulajainen, 2009).

Another technical issue is that the free passage season in NSR currently only runs from summer to autumn. To make NSR more commercially viable, timely and sufficient products for shipping in destinations (i.e. markets of Asia and Europe) and stop-by locations (i.e., local Russian markets) are critical. Thus, it is argued that a stable company financial status and high-level manager support are necessary to facilitate long-term investment in the potential of NSR (Lee and Kim, 2015). In the many models discussing NSR’s feasibility, different sailing speeds for summer and winter and by different researchers are considered, and all these factors are inextricably linked to technical issues of cost, logistics and information (Lasserre, 2014). One practical issue that NSR would help avoid according to the literature is that of piracy. NSR avoids both areas where piracy exists and also avoids politically unstable Middle Eastern Waters (Hong, 2012). This is not of course to suggest that piracy could not occur there.

2.2 Ships
To date, the research is somewhat conflicting regarding the size of vessels that can travel through NSR, possibly because the coastal route of NSR involves travel through the Sannikov Strait (Pastusiak, 2016), which has a limited depth, whereas the transit route is in more open, deeper seas. Whatever the reason, it is clearly an issue that companies need to carefully consider. For example, although Hong (2012) notes there are no vessel restrictions on NSR, and some Korean based research has found that bulk and oil tankers are more viable than containers for navigation in the NSR (Lee and Kim, 2015), others note the draft of vessels cannot exceed 13 metres owing to the limited depth of the Sannikov strait (Verny and Grigentin, 2009; Liu and Kronbak, 2010) and that this will impact on profitability (Stephenson et al., 2013). Also, ships must be ice-class, even when being escorted by an ice-breaker (Lindstad et al., 2016). Remaining sea ice will also increase the power requirement of ships. There are clear cost implications here. Furuichi and Otsuka (2013) note that such ships cost an extra 10-30 per cent to build and loans may be needed to pay for such ships (Verny and Grigentin, 2009; Liu and Kronbak, 2010). Significant engineering is required, including hull thickening, greater structural support, rudder and propeller protection and heating for fuel tanks (Liu and Kronbak, 2010). Nevertheless, such technology does exist (Ho, 2010; Hong, 2012), and there is a desire to build such ships, for example on the part of South Korea (Hong, 2012; Bennett, 2014), and they are listed on Lloyd’s register (Liu and Kronbak, 2010) making insurance matters more straightforward.

2.3 Costs
Put simply: “everything costs more for the shipping service in the Arctic” (Lasserre, 2014, p.155; compare also Tavasszy et al., 2011) and the range and complexity of costs involved in NSR is immense. Liu and Kronbak (2010) categorise these costs into capital costs (e.g. ships); voyage costs (e.g. toll fees); and operation costs, (e.g. insurance (both Protection and indemnity (P&I) and Hull & Machinery (H&M)). According to Somanathan et al. (2009), annual cost estimation of each ship type for a potential route should include both operating cost and capital recovery (or at least cost). The total cost of the whole fleet in one year thus includes operating cost, capital cost and payments and voyage cost (Lee and Kim, 2015). Operating costs include crew wages, repairs and maintenance, insurance fees and administration. Capital cost and payments include interests, debt repayment and depreciation. Voyage cost includes fuel consumption, supply of fresh water, port charges and pilot and ice-breaker tariffs. Regarding fuel costs, savings may be immense, but these
may be offset by the need for specialised types of fuel (Lasserre, 2014) and a low fuel price might make NSR less attractive (Pierre and Oliveier, 2015). Further, although some suggest slow steaming to reduce operational fuel costs (Tavasszy et al., 2011), this might not be possible given just in time requirements and navigation difficulties (Lasserre, 2014). Also, ice-class ships with reinforced hulls consume more fuel (Furuichi and Otsuka, 2013).

Insurance costs, although higher, are extremely hard to ascertain (Verny and Grigentin, 2009) and some insurers do not yet offer insurance (Lajeunesse, 2012). Further, there are costs for administration, tariffs, fees for guidance and meteorological information. Such costs are currently imposed by Russia, are approximately double those on the Suez route (Verny and Grigentin, 2009) and differ according to the specific NSR region (Liu and Kronbak, 2010), making cost calculations of this element highly complex. Another cost is the skilled crew required (Verny and Grigentin, 2009; Ho, 2010; Lajeunesse, 2012). A crew of 19 would cost US$100,000 per month (Verny and Grigentin, 2009). Some suggest introducing an Arctic Certificate (Laulajainen, 2009) as much technical support, know-how, navigation equipment, escort and experience is needed to take ships through NSR (Verny and Grigentin, 2009).

Nevertheless, these additional costs must be considered alongside the savings of NSR. Crews may be more expensive, but sailing time is much reduced, so the crew would not be needed for as long (Hong, 2012). Insurance may be higher, but the reduced risk of piracy (Hong, 2012; Furuichi and Otsuka, 2013) or kidnapping (Schøyen and Bråthen, 2011) is a positive and hull insurance is the same for ice-class and standard class ships (Laulajainen, 2009). On balance, some argue NSR could “cut the cost of a single voyage by a large container ship billions of dollars a year” (Hong, 2012, p.50). Often, conclusions of profitability are based on “what if” scenarios: for example, if ice-breaker fees are reduced by 85 per cent and bunker fees kept low then NSR will be “as economically competitive” as the Suez canal if open for 3 months (Liu and Kronbak, 2010, p.443). A recent review of models aimed to calculate the profitability of Arctic routes shows 13 concluded yes; 6 were ambivalent; and 7 concluded no (Lasserre, 2014). Nevertheless, such “conclusions must be handled with great care” (Lasserre, 2014, p. 151). Also, others note that, given the greater impact of emissions when they are released in the arctic area, the benefits of any fuel savings are overridden by the environmental costs involved, thus eliminating any cost benefits in savings on emissions from an environmental perspective (Lindstad et al., 2016).

With regard to the impacts on shippers and consignees, NSR could bring more sailing frequencies (loop) between Asia and Europe and consequently result in cost reduction owing to shorter sailing distances and lead times. Shippers could adjust their maritime supply chain deployment in response to the demand of consignees according to the sailing season (e.g. June to September) of NSR. Further, based on the effect of shorter transportation distance, NSR could bring potential benefits in production, logistics, warehouse and distribution costs for shippers and consignees.

2.4 Information about North Sea Route feasibility
The models and simulations calculating the feasibility of NSR differ quite significantly. Often, certain factors are omitted, some models do not compute NSR fees, others imagine crew costs to be the same on Arctic and standard routes, insurance premiums fluctuate greatly (Lasserre, 2014). In addition, some researchers commendably critique their own models for only including simulations using single, rather than multiple vessels (Liu and Kronbak, 2010). The difficulties of defining credible parameters for any model are also noted (Lasserre, 2014) as is the scarcity of Siberian route data (Schøyen and Bråthen, 2011).
Ascertaining NSR navigability is also highly complex. Historical data indicate rapid melting and significant increases in ice-free days (Schøyen and Bråthen, 2011) and, if some predictions are believed (Lovelock, 2009), NSR will very soon be navigable. Some claimed the Arctic Ocean would be navigable all year round by 2015 (Valsson, 2006). Others claim that a “blue” summertime Arctic Ocean could be from the middle of the century, although “current rates of warming indicate an earlier realization” (Ho, 2010, p. 713). Elsewhere however, a navigable season of only 90-100 days is not predicted until 2080, although thought to be a conservative prediction (Liu and Kronbak, 2010). Further, other literature cautiously observes that increased melting “may” lead to a longer navigation season (Hong, 2012, p. 50) or “could” rise to a certain level by 2080 (Pelletier and Lasserre, 2012, p. 559).

Fundamental to any NSR information is the specific method used to collect it. Some researchers use quantitative methods, others qualitative, others a mix. Some have used “informal discussions with actors in the maritime transport industry” (Verny and Grigentin, 2009, p. 108), others have used case study (Liu and Kronbak, 2010); interviews (12) and survey responses (18) (Lammers, 2009), email, telephone conversations and interviews (Schøyen and Bråthen, 2011); telephone interviews (Liu and Kronbak, 2010); qualitatively analysed surveys (Pelletier and Lasserre, 2012); model based analyses (Tavasszy et al., 2011) and Bayesian analyses (Afenyo et al., 2017). Many researchers highlight the drawbacks with their approaches, ranging from having too small a sample for quantitative analysis (Pelletier and Lasserre, 2012) to the difficulties of including everything in a model (Tavasszy et al., 2011). Regarding future research, many factors are suggested, such as including both quantitative and qualitative studies (Verny and Grigentin, 2009) and using quantitative modelling to help assess safety risk (Yang et al., 2013).

2.5 Other issues
Wider issues related to NSR involve possible political disputes over arctic waters (Ho, 2010; Hong, 2012; Wegge, 2015; Lee and Kim, 2015) and the need for clarification of legal issues (Hong, 2012) such as “an integrated governance and regulatory framework based on the United Nations Convention on the Law of the Sea” (Ho, 2010, p. 714). Further, whether the NSR should be considered as internal waters, territorial water, or international straits has debated for many years. Russia has claimed that most of NSR is under Russian jurisdiction (Flake, 2013), and many accept Russia will hold the rights to any NSR (Liu and Kronbak, 2010; Lajeunesse, 2012) and that rules and regulations for the Suez Canal are more transparent (Liu and Kronbak, 2010). Companies are thus subject to the political changes, rules and regulations of one particular country, unless an international law is passed. Therefore, uncertainties still remain in determining tariffs for the use of icebreakers and pilotage owing to the discretion of Russian authorities and negotiation with users.

Another issue is that the most benefit may be for companies wishing to extract natural resources, rather than for liner shipping, especially as arctic oil reserves are said to be comparable to Middle East reserves by some (Laulajainen, 2009), even if not by others (Pelletier and Lasserre, 2012). Indeed, Singapore and India have presented their interests in NSR, as it has plentiful natural resources (Ho, 2010). As a result, in the future, more shipping and natural resource exploration activities in NSR (including Arctic states and other countries which have interests in this area) might increase environmental risks (i.e. floating ice can strike tankers and barges and lead to oil spills, noise disturbance) to the marine ecosystem and residents along Siberian coast (Pierre and Oliveier, 2015). Satellite data monitoring shows the dangers to the environment of carrying wet bulk and how black carbon is associated with certain ship types (Mjelde et al., 2014). Sailing NSR could also have an impact on indigenous populations and the livelihood of indigenous species of whales and
need to be carefully monitored (Reeves et al., 2014). It is suggested that management of Arctic shipping needs to be carefully planned in advance to protect endangered species of whales such as the North Atlantic Whale (Reeves et al., 2012). Furthermore, the effects of climate change are not all positive, as global warming involves “an increase in the frequency and intensity of adverse weather events” (Ho, 2010, p. 713).

Another wider issue is the possibility of new alternative routes and of changes in existing routes. Firstly, it is possible that a Trans-Siberian land route could become more attractive with Russian investment (Verny and Grigentin, 2009). Secondly, the Suez canal is “expected to see several improvements in years to come” (Verny and Grigentin, 2009, p. 116) and even if NSR becomes popular, it will require vessel traffic systems to prevent narrow straits becoming “choke points” (Ho, 2010, p. 714).

2.6 Summary
The literature above shows that much is known about the feasibility of NSR but also that it is uncertain. NSR offers the greatest potential between Asia and Northern Europe and, compared to the Suez Canal, distances are cut by almost 40 per cent, making great savings in fuel and time. Some companies are keen to invest in NSR technology and ice-class ships. Yet, NSR may be subject to reduced service, higher hazard levels, ships cost more to build, crews and pilotage cost more, environmental spillages could be more damaging and ship owners may not benefit from reduced voyage times. Regarding uncertainties, it is unknown when NSR will be ice-free, or what are the exact journey times around the ice are, or which routes are available to all ship types. There is also uncertainty regarding the supply chain transport risks, if NSR benefits container shipping and that many currently unknown elements need to be in place for NSR to succeed, such as a polar code, improved SAR, improved infrastructure, political and legal agreements over tolls. We now describe our methodology and approach to interviewing some key NSR stakeholders from Shanghai and Taiwan regarding their thoughts on NSR.

3. Methodology
From November 2014 to March 2015 in Shanghai and Taiwan (Taipei, Taichung, Taoyuan, Kaohsiung), we conducted in-depth interviews with nine key stakeholders knowledgeable about NSR, including one government official, two professors, shipping experts in six liner companies and one bulk shipping company. As shown above (introduction), sailing NSR from ports in these areas would hugely reduce the amount of nautical miles required to reach ports in Europe. Thus, although ports in Japan and Korea are situated nearer NSR, those we consider here would gain huge savings through NSR. Furthermore, given the huge amounts of shipping that travel from these ports, NSR thus represents a huge opportunity for shipping companies based here.

In terms of their knowledge and experience of NSR, the nine shipping experts have extensive research and practical experience in the polar shipping field and six have sailing experience of NSR. Such experience included participation and involvement in many international shipping and port policies, including polar shipping issues; research into ship safety management of ice-breaking ships in the arctic area and; extensive sailing experience in the arctic area and extensive knowledge of polar weather conditions, ice class ships, crew training for the arctic area and other NSR-related aspects. Job titles included general manager, director, senior manager, captain and vice president, and the companies they worked for were ranked in the top 15 global shipping companies in 2014. Thus, they were stakeholders who could give perspectives on NSR from government perspectives, academic perspectives and both bulk and liner shipping industry perspectives. Importantly, they all
had significant recent knowledge and experience of NSR, and they were working in highly influential roles in Asian shipping. Thus, not only was their knowledge and experience key but also their influence and positions are also key in relation to any decisions made with regard to choosing to sail NSR at this point in time.

In terms of the backgrounds of the stakeholders we spoke to and how we identified our participants to ensure their background and experience was relevant to NSR, our aim with selecting a broad range of individuals rather than focus on a specific group was to gather a wide range of perspectives and knowledge. We felt this important, given that we wanted to create information to benefit those considering NSR, and we felt that this information would be more comprehensive and beneficial if it considered a broader range of perspectives. Such an approach we felt would be complementary to others that have focused on particular groups (e.g. shipping companies (Lee and Kim, 2015).

With regard to the key interview questions proposed and some follow-up questions, these focused on stakeholders’ knowledge about NSR and what they felt were the challenges and practical issues involved, as well as whether they felt NSR viable at the present time. These questions were deliberately relatively open and broad, for example:

Q1. What are your concerns if this route becomes a business route in the future?

Q2. Do you think NSR is a feasible alternative route to traditional shipping routes?

Q3. What are main challenges for the shipping industries if NSR become an alternative route between Asia and Europe?

Q4. Do you think NSR could bring cost reduction for shipping industries? If yes, why? If No, why?

Q5. Do you have any comments or thinking about this issue?

Such questions were deliberately open and broad so as not to bias the collection through questions overly specified by the researchers (Chenail, 2011) and to allow for more open dialogue (Bakhtin and Holquist, 1981).

We used interviews rather than questionnaires (Beveridge et al., 2016) or focus groups to access more in-depth views through dialogue (Bakhtin and Holquist, 1981) with individuals and also to avoid a situation whereby we were asking participants to choose from perspectives that we had selected, as would have been the case questionnaires (Galasiński and Kozłowska, 2010). The interviews were much freer and thus allowed participants to convey information we ourselves had not considered. In terms of the language used, the interviews were conducted in the participants’ native language (Cortazzi et al., 2011), recorded, transcribed verbatim by the interviewer to start the analysis (Bird, 2005), then translated into English using a goal oriented or “skopos” approach (Vermeer, 2004) which focused on the target language meaning rather than literal translation from the source language. These interviews were then verified by one of the authors, a native English speaker. Ethical approval was granted from the appropriate bodies and anonymity assured (Christians, 2011). Interviewees were assured that the interviews had been ethically approved and in this way felt freer to disclose information, thereby enhancing the validity of the interviews.

Interview data were analyzed using both objectivist and constructivist grounded theory approaches (cf. Charmaz, 2011). In essence, a grounded theory approach consists of one where data are approached from the “ground” with a “theory”. In other words, data are collected and then a theory is taken to the data to analyse it for the occurrence and frequency of particular themes and items (Glaser and Strauss, 1967). From this original construct,
grounded theory has developed and two key strains of the theory are now considered to be “objectivist” and “constructivist” (Charmaz, 2011). An objectivist approach analyses the data using already decided and pre-determined themes from the literature review and a constructivist grounded theory approach looks at the data but does so with very few already decided and pre-determined themes, and this therefore allowed for additional themes to emerge. In our analysis of the data for this paper, we used a combination of predetermined themes (i.e. objectivist grounded theory) and continually searched for emergent themes (i.e. constructivist). We found such an approach gave us the foundation of the predetermined key areas (objectivist) but at the same time offered the flexibility to explore new and emergent themes (constructivist). Our aim was to gather a wide range of items of theoretical occurrence (Flyvbjerg, 2006) and for consideration by others in their own context. It was in this paper therefore not an aim to seek any difference in participants’ answers in relation to their backgrounds, rather, the aim was to gather a body of data for comparison with current research and thinking. Further, rather than approach the data for the frequency of occurrence of items in a content analysis as would be done, for example, with survey questionnaire responses, the aim was instead to align the data with the sections we had reviewed in the literature, and thus the analysis was approached more thematically. In particular, our aim was not only to analyze where there was concurrence with the literature but also where participants referred to elements that we had not encountered in the literature. The latter we were particularly interested in as these elements were novel from a theoretical occurrence perspective (Flyvbjerg, 2006). This form of analysis of the data was more reliable and valid in the context of our own aim and approach (Pilcher and Cortazzi, 2016), as it helped build a more comprehensive list of items for consideration.

4. Results and analysis
Below we present and discuss our data with the twofold aim of showing where our stakeholders’ views corresponded with the literature, and where they differed or added to the literature. We cite stakeholder comments in italics and double quotation marks and bracket stakeholder background afterwards. All quotes are from participants and, although we refer to the literature in brackets throughout for comparison, we do not present any quotes from the literature, only from participants. As with the literature review, the sections we categorise our results by are: technical issues; ships; costs; information about NSR feasibility and other issues.

Our approach and our data are qualitative. In line with commonly adopted approaches for presenting and analysing qualitative data we do this in the form of quotes that are compared and contrasted with the literature. However, we present a summary of these results first here below in Table I: “Summary of key points and their implications”. We do this for three main reasons: to first give an overview of the key points noted by the stakeholders we spoke to; to secondly show how these points compare or expand on the literature, and thirdly to give a judgement of what the implications of these points are for NSR in our judgement. It is our intention that this initial summary will help contextualise the following more in-depth section as well as provide an overview and summary of the results and implications.

4.1 Technical issues
Regarding the practical issues of NSR, Stakeholders’ views correlated with much of the literature. Regarding navigation (Renfrow, 2006; Lajeunesse, 2012) stakeholders noted that “communication and navigation systems are quite important” (Liner shipping), that there is a need for an “electronic chart system” and “communication and navigation facilities” (Liner
<table>
<thead>
<tr>
<th>Category</th>
<th>Key stakeholder points reflected in the literature</th>
<th>Additional points not encountered in the literature</th>
<th>Implications for NSR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>4.1. Technical issues</strong></td>
<td>Navigation and communication is key, and ice is a key issue (Liner shipping; bulk shipping; Government of official) Infrastructure needs development (Liner shipping) Advantage in avoiding piracy (Liner shipping)  Highly variably transit times (bulk shipping)</td>
<td>Differs hugely from traditional navigation (bulk Shipping), and ice is extremely complex, changing and varied (bulk shipping; Liner shipping), and places huge stresses on ships (Liner shipping) Infrastructure requires much time and cost (Liner shipping). Channels will need dredging (Liner shipping)</td>
<td>Currently not feasible</td>
</tr>
<tr>
<td><strong>4.2. Ships</strong></td>
<td>Ships will need to be strengthened (Professor); will need to be insured (Government Of official; Liner shipping); will cost more (bulk shipping; Liner shipping) Russia will be able to provide the lead and has the best fleet of ice-worthy ships (Government of official; Liner shipping)</td>
<td>The route is not feasible in the short-term (Liner shipping) There are no commercial incentives for non-Russian operators (Professor) Much needs to be identified in terms of hidden costs (Liner shipping; bulk shipping) Crew need to be expert in navigating shallow waters (bulk shipping); survival skills and the complexity of ice (Liner shipping)</td>
<td>Only feasible if Russia takes the lead</td>
</tr>
<tr>
<td><strong>4.3. Costs</strong></td>
<td>Insurance will cost more (bulk shipping); Tolls and fees will also increase and rules should be drawn up (bulk shipping)</td>
<td>Not feasible for business (liner shipping) Data should be gathered and lessons learned from Russia (Liner shipping)</td>
<td>Not currently feasible, only for Russia</td>
</tr>
<tr>
<td><strong>4.4 Information about NSR's feasibility</strong></td>
<td>Many people lack knowledge of NSR (Liner shipping; Government official) Data are scarce (Liner shipping) Unclear when it will become ice-free (Government official; Liner shipping; Professor)</td>
<td>Not feasible for business (liner shipping) Data should be gathered and lessons learned from Russia (Liner shipping)</td>
<td>Not currently feasible</td>
</tr>
<tr>
<td><strong>4.5 Other issues</strong></td>
<td>Politically and internationally there are many issues (Professor; Government Official) Jurisdiction is a key issue, in particular how much jurisdiction Russia has (Liner shipping; bulk Shipping) Environment will be a key issue (bulk shipping) and the IMO should become involved to make it safer (Government Official)</td>
<td>Many issues need to be resolved before it becomes feasible</td>
<td>Many issues need to be resolved before it becomes feasible</td>
</tr>
</tbody>
</table>

Table 1. Summary of Key points and their implications.
Shipping) or “navigation and hydrographical support for arctic navigation, a navigation monitoring system” (Government official). Such “advanced electronic navigational aids should be installed along the route” (bulk shipping). In addition to these similarities with the literature, stakeholders comments added much detail about specific navigation systems, noting that “navigation and ship control along the NSR are different from traditional methods, they need to locate ice fields and then choose coastal navigation routes” (bulk shipping). Consequently, development of navigation systems would take “time and much cost to develop a communication system that is well applied in NSR” (Liner shipping). Further, although “Automatic Identification System (AIS) could track ship position […] it needs a base station to support the necessary data” (Liner shipping) and such data relies on artificial satellites (Liner shipping, Government official), but signals may be unstable in polar regions owing to poor weather, sea waves affecting antenna functioning, slow transmission speed, or confusion with other ships’ signals. It was also felt sailing safety should be ensured by a “navigational hydrographical, hydro meteorological navigation service” (Professor). Sometimes system types were suggested such as “GLONASS (Global Navigation Satellite System)/GPS navigation satellite systems” or a “suitable gyro erectional navigation facility when sailing in high latitude areas” (Liner shipping).

Stakeholders’ views also correlated with the literature (Hong, 2012) that there would be an advantage of “reducing risks when ships pass Somalia” (Liner shipping) and that ships, “can avoid pirate risk (e.g. Strait of Malacca and Suez Canal)” (Liner shipping). Also, the practical issue of not being able to fix exact sailing times (Lasserre, 2014) was also mentioned by stakeholders: “transit time via the NSR is highly variable and it depends on weather and ice conditions” (bulk shipping). Practical issues from ice affecting navigability (Hong, 2012) were also noted by stakeholders: “multi-year ice, especially in low concentrations, is a major hazard to shipping in this area” (Professor) and there is “dangerous drift (e.g. iceberg)” (Liner shipping).

However, stakeholders gave many additional details to those in the literature about the complexity and nature of the ice, that “it is difficult to anchor in ice areas, the helm can be broken owing to ice, there are incorrect magnetic fields and ship collisions” (Liner shipping). Further, the need to consider, “the thickness, the duration of the ice season, the extent of ice-free waters, temperature, wind, fog, darkness, the width of the channel, depth of water, permafrost, etc., these […] factors will affect the accurate positioning of ships” (bulk shipping). Also, that ships’ operational effectiveness is compromised by cold temperatures, as “when ice is present, it can impose additional loads on the hull, propulsion system and appendages” (Liner shipping).

Regarding infrastructure, the literature (Renfrow, 2006; Verny and Grigentin, 2009) highlights the need for more infrastructure and port facilities. Stakeholders concurred, noting that NSR “lacks sufficient infrastructure […] and lacks supply capabilities owing to the limited infrastructure around the port cities” (Liner shipping) but also noting that “it needs time and cost to construct adequate port facilities and infrastructure” (bulk shipping). Many factors, such as the need for SAR arose in both literature and stakeholder perspectives but stakeholders also noted additional factors such as the need for “navigation channel dredging” (Liner shipping).

Thus, regarding technical issues, our stakeholders were fully aware of all the issues we had seen in the literature and were better informed than we were. From this perspective, it is arguable that the likelihood of NSR becoming feasible looks further into the future than some of the literature would suggest. Such a pattern was repeated throughout all categories.
4.2 Ships

Many ship-related aspects from the literature were also noted by stakeholders. For example, the need for ships to withstand ice involved many aspects of design and engineering (Liu and Kronbak, 2010), related to “ship hull [...] and machinery construction rules” (Professor) and the fact that such ships were uncommon. That ships needed certification to be on Lloyds register (Liu and Kronbak, 2010) and that ships would need an “official certificate to make sure they are safe for sailing” (Government Official) or “certification from the International Association of Classification Societies” (Liner shipping). Regarding the cost of developing such ships, although Furuichi and Otsuka (2013) noted such ships cost an extra 10-30 per cent, the stakeholder view was that it would be higher: “about 20 ~ 30 per cent higher” (Liner shipping), or that it was “on average more expensive” (bulk shipping).

As noted above, the literature is divided on the issue of whether certain routes would have draft limitations (contrast Hong, 2012 and Liu and Kronbak, 2010). Our stakeholders felt similarly, some that there was an issue with ship drafts, noting that, “draft restriction is another problem” (bulk shipping) and that large ships, “must suit the [...] draft limitations for navigation through several straits via the NSR” (Liner shipping). Yet, one stakeholder felt draft limitations were not an issue, and in fact quite the converse compared to traditional routes:

There is a draft limitation in the Panama and Suez canal. Ships with a large deadweight must go round by Cape of Good Hope in South Africa or the southern point of South America. (Liner shipping).

Also similarly to the literature, one stakeholder noted that given the distances involved, “the volume of transportation must be sufficient since the sailing distance between Asia to Europe is very long” (Governmental official).

As with their knowledge of the practical issues, many stakeholders talked specifically about Russia’s fleet, noting Russia has “one of the best ice-breaking fleets in the world. Besides ice-breaking fleet, it includes [...] facilities for control and prevention of pollution of arctic waters” (Governmental official). Further, that “Russia has adopted nuclear-powered icebreakers in military projects” (Liner shipping) and that ice-breakers are able to “guide 1-4 ships to pass through the ice area” and that “two ice-breaking ships will be allocated to be the leading ship and the tail ship” (Liner shipping). Positively, one stakeholder noted that if demand for such ships increases, “it will also bring a business opportunity for the ship building industry” (Liner shipping). There was thus a clear feeling here that should NSR become operable, much of the SAR and guidance facilities could be provided by Russia.

4.3 Costs

Regarding the categorisation of costs, the literature has divided these into capital (ship related); voyage (e.g. tolls) and operation (e.g. insurance costs) (Liu and Kronbak, 2010). Occasionally, our stakeholders also categorised costs, but did so slightly differently, for example that

A ship’s running cost can be separated into the following three categories: Operation cost (including manning costs, stores and lubricants, repairs and maintenance, insurance, administration). Capital cost and payments (including interests, debt repayment, depreciation). Voyage cost (including fuel oil, port cost, canal due (if any), ice-breaking fee)” (Liner shipping).

Regarding the costs of individual elements, crew costs for NSR are higher according to the literature, for example that a crew of 19 would cost US$100,000 per month (Verny and Grigentin, 2009). Our stakeholders agreed, and whilst they only averred to crew cost being
higher, they gave many additional details about what NSR crew would need to know, such as that “shallow waters in the navigation routes passing along the northern coasts of Russia require increased attention and experience from ship crews” (bulk shipping). More specifically, crew would need “skill for surviving, using survival facilities in the low temperature environment, first aid and treatment, safe evacuation, ice/snow forecasting skill” (Liner shipping). Further, one stakeholder added that:

Captains must understand the composition of ice and its characteristics, operating in ice areas, hull stress due to ice and low temperatures, safe sailing operations, ice-breaking operations, and ship stability control (Liner shipping).

In terms of insurance and administration fees, echoing the literature, (Verny and Grigentin, 2009), stakeholders highlighted the importance of insurance, one commenting that “the insurance cost (including cargo and ship) will increase if the owners would like to try this route” (bulk shipping). Also, stakeholders highlighted the need for more rules and regulations regarding tolls and fee charging (Hong, 2012), one stakeholder noting that:

Rules and regulations should be established and developed by the International Maritime Organisation (IMO). Many shipping companies would hope that fee charging for travelling the NSR should be realistic, acceptable and predictable (bulk shipping).

As far as NSR’s feasibility was concerned the literature often focused on events and possibilities, such as an 85 per cent reduction in ice-breaker fees improving feasibility (Liu and Kronbak, 2010), or that 13 of 26 studies concluded NSR was profitable (Lasserre, 2014). For stakeholders, it was often more in the long-term NSR would become feasible, for example that “this route does not have commerce feasibility in the short term” (Liner shipping) or that NSR “might bring some benefits to shipping companies at first glance […] however […] it cannot save much money at this time” (Liner shipping). Also, even where companies had actually sailed NSR and saved “9 days sailing compared to the traditional route […] but some analysts indicated that it needs time to make it a popular sailing route since it lacks port infrastructure” (Liner shipping).

As with other aspects above, our stakeholders mentioned additional elements to the literature. One was linking costs to the Russian context, for example that, “I do not see commercial incentives for the use of NSR for non-Russian operators” (Professor). Other cost related elements were, in line with the element of known unknowns, what were termed “hidden” costs, that NSR would “increase hidden costs and could affect their service quality” (Liner shipping) or simply that “the hidden costs require further calculation” (bulk shipping). Examples of these were often ones noted in the literature but also others such as “cargo damage due to low temperature and temperature variation” (bulk shipping) were noted.

4.4 Information about North Sea Route’s feasibility
Resonant with the literature commenting on the complexity of drawing conclusions about NSR (Lasserre, 2014), our stakeholders commented that many people lacked knowledge about NSR. For example, that “many shipping operators do not understand this area well since there exists many uncertain factors that need to be considered” (Liner shipping) and that “Many shipping operators have a poor understanding of the Arctic environment” (Government official). Also, as in the literature (cf. Schøyen and Bråthen, 2011), the scarcity of data was noted, one stakeholder saying “there is no correct sailing data in the polar area. Maybe only Russia has this kind of sailing data” (Liner shipping).
Also resonant of the literature, our stakeholders had divergent views on when NSR would become ice-free. One stakeholder commented that “one expert predicted ships might sail the NSR over four seasons by the year 2030” (Liner shipping). Another commented on the importance of minerals and resources: “NSR [...] could be another alternative place to purchase energy for China. Therefore, it could drive the trade development between China and the Arctic countries” (Liner shipping). The sense of inevitability of NSR opening up was alluded to, with the fact that “In summer 2009, the first international ship has passed through the NSR” (Liner shipping) or that “in the future, global shipping network will be reshaped by the NSR and form a new picture of the shipping network” (Professor). One stakeholder believed a pioneering company would take the lead for NSR, then others would follow:

It should be a pioneer such as Maersk line since it is the top shipping company in the world. Then, other shipping companies (e.g. Mediterranean Shipping Company (MSC), CMA CGM Group) might follow it in order to maintain the market position (Governmental official).

In contrast though, one of our stakeholders from Maersk, commented that, “this route is mainly used for military affairs and strategies [...] For business consideration, there is no shipping company would like to choose this route” (Liner shipping).

In relation to methods that could be used to gather data, our stakeholders occasionally suggested methods that were additional or complementary to those previously used by researchers. One additional method was to use scientific methods to gather and calculate data form the sea itself:

To understand and predict the extent of the arctic sea ice and multiyear sea ice changes, we should adopt scientific instruments and methods to simulate sea ice variables on seasonal, decadal and century time scales (Professor).

A complementary suggestion was to use interviews (Lammers, 2009) but to consult directly with Russian stakeholders and also to cooperate to learn from others:

I suggest to learn from the Russian experience and study how to build a firm and solid ship [...] in the future, shipping experts and polar experts should cooperate and exchange learning experiences (Liner shipping).

4.5 Other issues

The wider issues of political jurisdiction and the need for international codes (cf. Liu and Kronbak, 2010; Hong, 2012) were noted by our stakeholders. It was noted that “political sensitivity surrounds this area” (Professor) and that “Canada and Russia have both claimed the Arctic waterways as internal waters that pass through their Arctic region” (Governmental official). There was a tension where on one hand participants felt NSR waters should be international but on the other understood that Russia and Canada would want jurisdiction. For example that, “Russia views it as a domestic traffic route but other countries view it as an international traffic route” and this means that:

Russia requires other countries’ ships to obtain sailing permission from Russia in advance and pay fees for ice-breaking and navigation services. Other countries might not agree [...] and will be afraid if it increases such a fee in the future. Such a fee should be formulated by international organizations such as IMO (Liner shipping).

Similarly, that “Russia presents some rules and regulations for international shipping in this area, yet many countries will argue against the Russian regulation policies” and that “for fair usage principle in this route, it should be treated as international waters” (bulk
shippping). Nevertheless, one stakeholder understood why Russia would want jurisdiction, but felt the waters should be international:

It could be easily understood that Russia [...] would like to keep involvement in the NSR [...] since ships will bring pollution problems. However, the claims [...] would increase the complexity of NSR for shipping activities. For example, Russia has presented “Regulations for Navigation on the Seaways of the Northern Sea Route” and that affects the intention of sailing along NSR for the world shipping industry as a whole (Liner shipping).

Indeed, the wider issue of environmental damage was noted by many stakeholders. One noted that as shipping operators are unfamiliar with NSR:

The risk of ship accidents will be higher, thereby increasing the risk of accidental release of oil spill. This will bring serious impacts on the environment and regional development, especially in high production periods (bulk shipping).

Regarding possible actions to mitigate against such dangers, one stakeholder suggested taxes to deal with the issues: “carbon tax or fuel tax might be levied in this area in the future” (Professor) and another suggested a forum for environmental and other issues:

We hope the shipping operators or IMO could create a user forum where shipping stakeholders could give feedback and suggestions to make it safer and environmentally considerate and bring sustainable economic and financial benefits (Government official).

5. Discussion
Taking into consideration what our stakeholders said, the feasibility of NSR for companies in China and Taiwan appears to be a more long term prospect than much of the literature would suggest. Positively, the literature notes that trade is set to increase, ports in China set to grow, and NSR has significant potential to save huge amounts of time and money compared to traditional routes and that a number of companies are keen to invest in NSR technology and ice-class ships. However, on NSR, service may be reduced, higher hazard levels exist, ships will be more expensive, crew training will cost more, environmental spillages could be more damaging, ship owners may not benefit as much and that more research is needed. From the perceptions of our stakeholders, these issues were all key ones that they were fully aware of, but our stakeholders also were aware of a number of further issues. Our stakeholders commented on the unique difference in navigational approaches in polar regions, on ship horsepower, on the effect of temperature on cargo and the high cost of cargo. Furthermore, stakeholders were fully aware of the many different types of ice, ice floes, ice thickness and ice layers. Nevertheless, the perception as well that Russia has both the equipment and the expertise to help make NSR more feasible. Clearly then, there was a perception that NSR was very much of one whereby Russia would take the lead and that without this, the feasibility of NSR would be much reduced. In addition, from our stakeholders’ perspectives, the possibility of a frequently navigated and used NSR appears more distant than according to much of the literature.

Regarding uncertainties, the literature notes it is uncertain when NSR will be ice-free, how long a journey may take, or which routes are available to all ship types. Another uncertainty is that of supply chain transport risks, whether NSR is of benefit for container shipping, and that a number of elements need to be in place for NSR to succeed such as a polar code, improved SAR, improved infrastructure and political and legal
agreements over tolls. Again, our stakeholders were fully aware of all these uncertainties, and also they were fully aware of a number of additional uncertainties. Firstly, it is uncertain what navigation system will be most suitable. Secondly, it is uncertain how much time will be needed to develop the infrastructure. Thirdly, the number of hidden costs is uncertain, and we do not know a lot of information because we would need to collect it directly from the arctic sea or from Russian experts. Fourthly, we do not know how much fuel will increase by in price and that this could affect NSR, and finally, we do not know when or even if international treaties will be introduced or whether jurisdiction will remain with Russia. Thus, again, from our stakeholders’ perspectives, the feasibility of a frequently used and navigated NSR appears more distant in the future than it does in much of the literature. Is this a concern for the shipping industry? Should it be? At the moment, much of the literature appears imbued with an inevitability regarding NSR: it will happen, it is just a case of when. Yet, as the literature shows, this “just a case of when” is extremely uncertain. Furthermore, the views of the stakeholders we interviewed here would suggest that, unless someone or something takes a lead on NSR, its feasibility is in the distant rather than the more immediate future for these companies in China and Taiwan, two key areas that could benefit from any NSR were it to become feasible. This is our stakeholders seemed to intimate that Russia would be one country that could take a lead given its expertise and geographical oversight of the majority of NSR. But should Russia take a lead? Perhaps it should do so in tandem with the IMO? Arguably, we would suggest that future research could conduct quantitative analyses of cost-based focuses to ascertain the benefits of forcing the issue of NSR. If such analyses show that, all things considered, NSR would be beneficial to the shipping industry, then perhaps the IMO should indeed take a lead on NSR, perhaps in tandem with a country such as Russia.

6. Conclusion
Owing to the sea ice in polar regions gradually retreating, shipping in NSR attracts interest from the shipping related industries in the world. The potential of NSR is a tantalising one that could dramatically reduce shipping times and costs from Asia to Europe, and, according to some literature, this is something that could happen fairly soon, if not imminently. The literature has noted a number of practical issues nonetheless and also a number of considerations with regard to ships, costs, information about NSR and also wider issues. Practical issues relate to navigability, SAR, weather conditions and infrastructure, ships must be specially engineered for the conditions and costs of crew training and insurance are key. Regarding information about NSR and wider issues, the literature notes the complexities of ascertaining certain information regarding NSR, wider issues of who should govern the route and issues related to the environment and rights of the indigenous populations. Furthermore, survey research with Asian companies suggests that at the current time the route is not considered feasible. We complemented this literature by conducting in-depth interviews with nine key stakeholders with extensive research, knowledge and practical experience in the polar shipping field from China and Taiwan. This is despite there being more advocacy for Korea (Bennett, 2014) and Japan (Usami et al., 2016) to adopt the route and for more optimistic predictions about its use by China (Hong, 2012). Their perceptions reveal current thinking regarding the feasibility of NSR, and, given their positions and influence, represent a view of significant power in the context of any decisions made regarding whether NSR is used. All none stakeholders were aware of all the issues we had encountered in the literature and far more. For example, their knowledge of the
practicalities were often far more refined, for example regarding different types of navigation systems. Further, their estimates were often higher than those of the literature, for example, estimating ship costs higher than the literature. They also felt that without one country taking the lead in developing NSR, its feasibility was far more theoretical than practical.

In terms of shipping therefore, the perceptions and current thinking of the stakeholders we interviewed suggests that the feasibility of NSR is a more distant one than much of the literature suggests. The literature, we noted, almost seems imbued with an inevitability with regard to the feasibility and opening of NSR, but such an inevitability is not borne out by those we spoke to, many of whom work directly in the shipping industry itself. Should the issue be forced? Should someone take a lead on NSR? Our stakeholders tended to intimate that if anyone did it would be Russia, given their knowledge, expertise in shipping and their geographical proximity with much of NSR. We suggested also that the IMO may want to become involved in something that investigated and suggested that to determine whether the issue of the feasibility of NSR was worth forcing, that analyses focusing on cost-benefits would be useful. By undertaking such analyses to an extent that could incorporate all elements involved would reveal whether the issue was indeed worth forcing, or whether the shipping industry should instead simply wait for the theory of a navigable NSR to become a practical reality, whenever that may be.

Notes

References


Further reading


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An evaluation of mid-stream operation in Hong Kong

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Abstract

Purpose – Mid-stream operation has had a significant role in Hong Kong’s economic development since the 1960s. Prior to the building of container terminals in Hong Kong, cargo was mainly loaded onto and discharged from ocean-going vessels by mid-stream operations and then shipped to Europe and North America. This paper aims to reinforce mid-stream operation is considered a “must” in supporting the substantial growth of maritime industry and strengthening Hong Kong’s role as an entrepôt.

Design/methodology/approach – The authors undertake a historical review of the evolution of Hong Kong’s mid-stream operation over the past half-century and investigate the future of mid-stream operation in light of the Hong Kong Special Administrative Region government’s policy of allocating Public Cargo Working Areas through an open auction process. Semi-structured, in-depth interviews are also undertaken in this study.

Findings – The emergence of container terminals generated competition for cargo between container terminals and mid-stream operators. In addition, the Hong Kong Special Administrative Region government’s policy of allocating Public Cargo Working Areas to mid-stream operators through an open auction process intensified negative influences on the survival of the mid-stream operation sector.

Originality/value – To date, mid-stream operation has been abandoned nearly everywhere except in Hong Kong. Yet, Hong Kong’s container system has become the most advanced in the world. The authors explain how and why mid-stream operation still plays such a key role in Hong Kong and how to enhance its sustainability. The authors also discuss the academic and managerial implications of their findings.

Keywords Hong Kong, Sustainability, Container terminal, Mid-stream operation, Public Cargo working

Paper type Research paper

1. Introduction

Hong Kong has one of the most productive container ports in the world. One of the port’s oldest industries, mid-stream operation (MSO), currently supports around one-quarter of
MSO is characteristic of shipping in Hong Kong and an essential part of the Hong Kong logistics industry. According to the Port Development Board (formerly the Hong Kong Port Development Council), by the early 1990s, there were 2,000 privately owned lighters servicing ships moored mid-stream and about 200 lighters “specially designed” to carry containers. MSO can be more efficient than container terminals in some respects – for instance, by offering lower initial costs and more diverse and flexible services. MSO mitigates container traffic at terminals by reducing their workload, and it constitutes a specialised shipping market. It strengthens Hong Kong’s role as an international shipping hub in a competitive environment.

Despite MSO’s role in supporting import and export trading in Hong Kong, the Hong Kong Special Administrative Region (HKSAR) government has historically had a complacent attitude towards MSO. In 1992, the HKSAR government proposed to establish the River Trade Terminal in Tuen Mun to “operate as a consolidation point for containers and bulk cargoes shipped between the Port of Hong Kong and the Pearl River Delta as well as between the Port of Hong Kong and the inland waterways in Guangdong and Guangxi Provinces” (Port and Maritime Board, 2000; Dufour et al., 2009). For cargo located near waterways, river trade is more cost-effective than overland hauling, as a river craft can move more containers than a tractor-trailer. As the clientele of the River Trade Terminal overlaps with that of MSO, the River Trade Terminal has decreased MSO’s share in the cargo-handling business.

To generate profits and support sustainable business development, the HKSAR government allows terminal operators to lease parcels of the dedicated shoreline by auction. The auction operates as a private market, with no consideration of MSO as a related and supporting industry. As a result, public cargo working areas (PCWAs) are likely to be reduced dramatically. It is expected that three out of the existing eight PCWAs will be phased out progressively by 2020 [GHK (Hong Kong) Ltd., 2004]. The operation of PCWAs involves the short-term allocation of berths and waterfront working areas for the purpose of handling containers (35 per cent of total weight of cargo handled), sand and aggregate (17 per cent), waste paper (12 per cent), cement (11 per cent) and construction materials (8 per cent) transferred between lorries and barges (HKSAR Legco, 2016). The PCWAs are waterfront areas managed by the HKSAR government’s Marine Department where the cargo transfer operations are conducted by a large network of relatively small and long-established family firms (Dufour et al., 2009). The decreasing number of PCWAs adversely affects the movement of cargo and operating efficiency in the various seafronts of the harbour. Furthermore, MSO has inherent weaknesses in its operation chain that put it at a competitive disadvantage,
such as insufficient land sites for repositioning, limitations on the size of buoys that are a barrier to the operation of larger vessels at mid-stream sites, inefficient equipment and a lack of sheltered waters for anchorages (HKSAR Legco, 1993). Thus, the HKSAR government offers minimal assistance to and investment in MSO. Starting in 1991, the HKSAR Legislative Council began discussing MSO. However, the council underestimated the potential of MSO (HKSAR Legco, 1991) and further undermined MSO in the years thereafter (HKSAR Legco, 2013).

Since 2008, MSO has faced significant changes in its operational environment:

- PCWAs near the Central Business District (CBD) were recalled and reallocated for other purposes.
- The original allocation of PCWAs was conducted under short-term tenancy from the government. From 2008 onward, the allocation of PCWAs has gone through an open auction process that has increased the overhead costs of MSO.
- There have been a number of accidents, mostly caused by Pearl River Delta barge operators, which have forced the government to take an active role in supervising the safety of MSO.
- Safety concerns have led to restrictions on the maximum number of containers that may be loaded onto a barge.

We have identified three critical issues that may lead to significant changes for MSO in Hong Kong: the reduction of PCWAs, the auctioning of shoreline and the opening of the River Trade Terminal. MSO has been ignored in the maritime transport research. To fill in the research gap, we aim to address the evolution of MSO in Hong Kong and its role in Hong Kong’s maritime industry. Below, we try first to identify the forces currently diminishing the role of MSO in Hong Kong’s maritime industry and second to determine whether MSO should be abolished in the future. The rest of this paper is structured as follows. Section 2 describes the history of Hong Kong’s port development. Section 3 discusses the evolution of MSO in Hong Kong and examines the present operating environment of MSO in Hong Kong. Section 4 concludes the paper.

### 2. History of Hong Kong port development

Hong Kong is one of the largest ports in the world. Its long maritime tradition began in August 1842. After the signing of the Treaty of Nanjing, Hong Kong was officially under British colonial rule. Evidence of the development of shipping and entrepôt trade was first recorded in 1844. The coolie trade contributed to the growth of shipping in Hong Kong. In response to the growth of international trade, Hong Kong evolved from an entrepôt to an international port between 1899 and 1940. Prior to the construction of container terminals, standardised containers were only handled at three facilities: the North Point Wharves, the Kowloon Docks and the Kowloon Wharves of Hong Kong and Kowloon Wharf and Godown Co Ltd (Marine Department, 2017). A 1966 report on containerisation suggested that Kwai Chung should be Hong Kong’s purpose-built container terminal (Seabrooke et al., 2003). Construction of the first three terminals began in 1970. Symbolic of the containerisation era is the first container ship to visit the terminal: *Tokyo Bay*, of Overseas Container Lines (P&O Nedlloyd), used the Kwai Chung Container Terminals in September 1972. Hong Kong boasted that the port “has a worldwide reputation for catering to the requirements of modern shipping” (Loughlin and Pannell, 2010). In the 1970s, two terminals were in
operation at the Kwai Chung Container Terminals. Terminal 1 was run by Modern Terminals Limited beginning in 1972. In 1974, work on Terminal 4 commenced on behalf of Hong Kong International Terminals. Modern Terminals Limited and Hong Kong International Terminals became the main operators at the Kwai Chung Container Terminals (Wang, 1998; Airriess, 2001).

Deng Xiaoping carried out economic reforms to achieve a “socialist market economy” and implemented an “open-door” policy in 1978 (Airriess, 2001; Cullinane et al., 2004; Zhang et al., 2005). These liberalisation policies generated significant growth in trade volume and traffic. After Shenzhen became a Special Economic Zone, Hong Kong’s manufacturing sector shifted to the Pearl River Delta due to low land and labour costs. More manufacturers used Hong Kong for export because while China’s ports had not containerised, Hong Kong was reputed to have world-leading container terminal facilities during this period (Wang, 1998). Aided by China’s favourable trade policies, the Hong Kong port rode the waves of containerisation and Chinese economic growth. It expanded significantly with Terminals 4, 6, 7 and 8, while throughput at both Kwai Chung and Hong Kong International Terminals reached new peaks. Because of dramatically increased demand, the Hong Kong government carried out the Port Development Strategy Study, which recommended a development program and strategy for the construction of major new port facilities in Hong Kong (Marine Department, 2017). Between 1986 and 1996, Hong Kong’s throughput reached double-digit growth, and Hong Kong firmly established itself as a global logistics hub (Wang, 1998; Wang and Slack, 2000; Yeung et al., 2004; Fu et al., 2010). The total container throughput of Hong Kong grew from 9.2 million TEUs in 1993 to more than 19.1 million TEUs in 2002 (Yeung et al., 2004). In the 1990s, Hong Kong maintained its position as the world’s busiest port measured by container throughput (Wang and Slack, 2000; Loo and Hook, 2002; Seabrooke et al., 2003). To enlarge container terminal capacity, Terminal 9 was opened in 2004 on the southeastern shoreline of Tsing Yi Island. The enlargement of what was now known as the Kwai Tsing Container Terminals (formerly the Kwai Chung Container Terminals) helped Hong Kong to keep its role as one of the leading ports for southern China in the twenty-first century (Marine Department, 2017).

Basically, MSO is not a heavy capital investment as the operation has no need of wharf. Thus, MSO rates are about ½ to 1/3 of the container rate at container terminals. MSO is a primitive way of container handling. MSO flourished in Hong Kong when there was a shortage of handling capacity for the container terminal in Hong Kong and South China. The 1990s saw continuous growth and the consolidation of a unique kind of container-handling mode in Hong Kong, MSO. MSO contributes to the service flexibility of the Port of Hong Kong by offering smaller container ships the ability to lie at secure buoys in the harbour and be unloaded by barge. This relieves congestion and bottlenecks on port infrastructure. In the long term, this increases container terminals’ capacity and encourages the port to operate efficiently (Wang, 1998). Besides, MSO creates another choice of shipping lines to handle their business, rather than at terminal, therefore supporting to generate a balanced market mechanism. It has strengthened Hong Kong’s position as the regional hub port (HKSAR Legco, 1999). Furthermore, MSO suits the characteristics of some trading activities like the west-bound trade of Taiwan to Hong Kong or South China trade when an ocean going vessel discharge full container loads (FCLs) to be carried to many river ports in Pearl River Delta (PRD). Container can be discharged into river trade vessels/barges directly without the need to pass through the terminal. Operational cost will be decreased significantly.
3. Methodology
A qualitative research approach has been adopted to gather substantial unpublished, qualitative information. Apart from historical and legislative documents, the researchers carried out seven semi-structured, in-depth interviews with key personnel. Because of confidentiality agreements, all details of the interviewees are excluded in our reporting. The target interviewees are held in supervisory and managerial job position of maritime industry ranging from liner firm, terminal and maritime logistics associations. The interview questions are mainly focused on the current and further development for MSO; the comparative advantages of container terminal and MSO; MSO contribution to Hong Kong development; the critical factors to sustain MSO in Asia-Pacific; the regulatory issues relevant with the development of MSO; and the changes and pressures that happened at MSO after the introduction of container terminal.

4. Mid-stream operation
4.1 History of mid-stream operation
According to Wan (2009), MSO has played a significant role in the economy of Hong Kong since the 1960s. Prior the containerisation period, MSO provided the cargo handling service for ocean-going vessels. In 2015, 4,175 persons engaged in the MSO sector which provides direct and indirect employment opportunities. Also, MSO obtained HKD5.6bn revenue (Census and Statistics Department, HKSAR, 2017). In other words, MSO continue contributing to the well-being of Hong Kong economy. Hong Kong was already one of the major manufacturing cities in the global market at that time, and commodities from mainland China were transported to Hong Kong for re-export beginning in the 1980s. Long before container terminals were established, products were loaded and unloaded from ocean-going vessels by MSO and then shipped to North America and Europe. However, by the twenty-first century, the relocation of manufacturing industries in Hong Kong and the development of sophisticated ports for sea-freight transport and container services in southern China threatened the survival of MSO in Hong Kong.

Currently, there are three main components of Hong Kong container throughput. MSO is one of them. Hong Kong MSO has handled containers since the early 1970s. In November 1972, the UN held the world’s first Conference on International Container Traffic in Geneva, Switzerland, to which over 120 nations and organisations sent delegates. The concept of containerisation was widely accepted by delegates, which led to the governance of ship particulars, capability and safety by the International Standardisation Organisation and International Maritime Organisation and the replacement of the traditional Break-Bulk Marine Transport Model by the Containerisation Marine Transport Model (HKMOA, 2017). Prior to the introduction of containers, ships in MSO were built from wood. Bulk cargo was moved to wooden barges, which were then towed to the shore by tugs. The kinds of cargo being carried were diverse and included bricks, sugar cane and fresh and frozen food from mainland China and rice from Southeast Asia. Beginning in the 1950s, steel barges were used, increasing capacity and stability. Materials such as sand, metals and stone could now be handled by MSO (Marine Department, 2017). At the same time, Hong Kong, though blessed with a natural harbour, lacked a container terminal. To meet market demand, in the early 1970s, the British colonial government issued a grant to a private terminal developer to construct a container terminal with three berths at Rambler Channel near Kwai Chung Sea Bed. However, the three berths faced capacity
constraints, notably during peak hours. Vessels were required to wait for berths, which disrupted shipping lines' schedules and raised their costs. That motivated shipping lines to consider the use of derrick barges to load and discharge containers from waiting vessels, contributing to the development of the now-familiar operational model of MSO (HKMOA, 2017). Although MSO does not involve large ships, it has contributed to a significant percentage of total throughput since the 1980s, especially when the container terminals were near their maximum capacities (Marine Department, 2017).

Due to containerisation, the international shipping industry grew significantly. To ease berth congestion, the British colonial government proposed providing more land to establish additional container terminals. Four container terminals with a total of 14 berths were opened by private developers under various terms and conditions in 1976, 1985, 1988 and 1991. Container throughput increased at a faster pace than the number of available berths; however, mainland container terminals had not yet fully developed leads to trans-ocean shipping lines and failed to call mainland ports directly. As a result, there was an on-going shortage of container berths that continues to the present day. Although Hong Kong-China feeder services were expanded rapidly, MSO achieved record performance into the early 1990s. Further, derrick barges were modified and enlarged for use in MSO. MSO thus made a dramatic contribution to Hong Kong’s port development (HKMOA, 2017).

The Port Control (Cargo Working Areas) Ordinance (Cap 81) established PCWAs to help meet demand in 1974. The first PCWA was set up in Wan Chai, and berths were allocated on a first come, first served basis. The Marine Department controlled two public waterfronts and nine PCWAs. In this period, all PCWAs were open daily from 0700 to 2100 and upon special application. The PCWAs have been provided a larger strip of land behind the waterfront for cargo handling, and with some modern handling equipment. PCWAs are seafronts for MSO cargo operations managed by the cargo handling section. On the whole, a PCWA aims to foster MSO operators to carry out cargo transfer across vanning, seawall and devanning operations (Marine Department, 2017). In the past two decades, MSO has been significantly developed and modified. The government allocated two pieces of land with an area of 6.9 hectares for MSO on a 50-year basis under open tender to the public near Stonecutter Island. The tender awarded land to design and plan an operation that would perform at a level as near as possible to that of Kwai Chung Container Terminals. Because charges for the use of the container pier were and are relatively high and the supply of land is inadequate, MSO has endured in Hong Kong (HKMOA, 2017).

4.2 Current trends in mid-stream operation

Land is the scarcest commodity in Hong Kong. No wharves with proper cargo cranes have been installed in the territory to handle traditional cargo. Hong Kong relies on MSO to supplement services provided for the import and export of container and bulk cargo. MSO has two requirements. The first is a movable container barge with its own derrick crane, called a lighter. The second is a shallow water depth (5 m) (Kim and Morrison, 2012). MSO involves the loading and unloading of containers to and from cargo ships while at sea, with barges or dumb steel lighters performing the transfer and the distribution of containers occurring at piers nearby. Ocean-going vessels do not need to berth alongside for cargo loading and unloading; they simply drop anchor at mooring buoys and discharge their cargo with the help of single-derrick cranes installed on board local dumb steel lighters. This kind of derrick crane-equipped
lighter is unique to Hong Kong, and MSO is seldom used outside of Hong Kong (Fung, 2002; Yip et al., 2002; Gunaskaran and Ngai, 2004; Green Cross, 2010; Fu et al., 2010; Loughlin and Pannell, 2010). Traditional MSO in Hong Kong is illustrated in Plate 1.

In the maritime industry, Hong Kong has become the only place in the world with at-sea loading and unloading operations. MSO in Hong Kong has boomed. At present, 28 shipping lines use MSO. In Hong Kong, MSO takes place at 11 different locations (e.g. Western District, Chai Wan, Yau Ma Tei, Stonecutters Island, Rambler Channel, Tuen Mun, Lamma Island, etc.) occupying a total land area of 24 hectares and water frontage of 4,936 m. At present, the main MSO operators include Fat Kee Stevedores Ltd (2017), Tai Wah Sea/Land Heavy Transportation Ltd and Transward Ltd. Currently, the berth width of Chai Wan PCWA is 40 m, that of Stonecutter Island PCWA is 50 m and that of Rambler Channel PCWA is between 20 and 30 m (Marine Department, 2017).

4.3 Advantages and disadvantages of mid-stream operation

MSO has demonstrated seven key advantages. It:

(1) can be rapidly removed, deployed, expanded and relocated;
(2) is minimally affected by seabed provisions;
(3) needs no foundation work;
(4) can be established in a large number of locations;
(5) causes no ground subsidence;

Plate 1.
Traditional MSO in Hong Kong

Source: Author
has a low impact on the environment (Kim and Morrison, 2012); and
has low costs (Fu et al., 2010).

However, MSO faces pitfalls, as it:

- is affected by weather conditions;
- is disrupted or damaged by serious waves;
- needs stabilisation or mooring systems; and
- has increased operational costs and has a short life cycle (Kim and Morrison, 2012).

MSO is inefficient, as the vessels that carry it out are not self-propelled but towed (Malchow, 2012; Kim and Morrison, 2012). Researchers criticise MSO for the danger involved in transferring cargo between two ships at sea, a very difficult operation. Workers must stay at the top of high stacks or in cramped spaces in cargo holds so as to guide containers into twist locks at their four corners. The slewing mechanism relies on the combination of a wire drum, a counterweight and a manually applied foot brake. This cargo handling technology hardly complies with international safety standards (Green Cross, 2010; Malchow, 2012). Four fatal accidents occur in MSO on yearly average (Marine Department, 2017).

4.4 Future challenges for mid-stream operation

Hong Kong handled 21 million TEUs of containers in 2009. Of that total, 74 per cent were handled by container terminals at Kwai Tsing Container Terminals, with the rest handled mid-stream by Hong Kong’s mooring buoys and river trade facilities. In the early 1990s, more than 30 per cent of all containers were handled by MSO. At present, only approximately 10 per cent of the huge port’s container throughput of 24 million TEUs is left to this unique cargo handling operation (Malchow, 2012; Kim and Morrison, 2012). In 2015, Hong Kong handled 20.1 million TEUs; only around 4.5 million TEUs were handled by MSO (Marine Department, 2017). The moorings also handle most of Hong Kong’s break-bulk cargo. Bulk shipping handles bulky, unpacked goods such as oil, gas, grain, minerals and timber. Figure 1 summarises Hong Kong container throughput involving Kwai Tsing Container Terminals, the River Trade Terminal and MSO.

MSO in Hong Kong augments container terminals so that they have more capacity to meet the high demand for terminal services. More container terminals were completed and put into operation over the past 10 years. MSO has complemented terminal operations due to the functions of MSO in Hong Kong both as a transhipment point between barges and ocean-going vessels (especially for intra-Asia lanes) and as a consolidation point for barges dispatching cargo to the Kwai Tsing Container Terminals (Europe or America). MSO and container terminals cater to different customer needs (Fung, 2002; Dufour et al., 2008; Dufour et al., 2009; Fu et al., 2010).

The next few years are expected to see significant changes in the mix of the port’s container-handling services as additional capacity is added and as the Hong Kong container terminals compete with nearby ports in South China, particularly Shenzhen Port (Zhang et al., 2005; Fu et al., 2010). While MSO is a low-cost operation compared to container terminals, some higher-value cargo on larger vessels may be better suited to the terminals. Because MSO only involves transferring cargo from ships at anchorages and buoys, its fees are 40-60 per cent lower than shore operations (i.e. terminal handling charges), and MSO also acts as a valve for overflow from shore
operations. However, limitations on equipment pose a technical upper limit on the size of ship that is appropriate for MSO. In general, only 21.1 per cent of cargo is handled by MSO (Marine Department, 2017), and MSOs contribute about 2.3 per cent to the economic viability in Hong Kong (Census and Statistics Department, HKSAR, 2017). To retain flexibility to respond to changing volumes, we recommend that the current mix of long- and short-term tenancies be retained with some short-term tenancies extended to encourage greater investment in facilities to increase throughput and efficiency. The possibility and feasibility of upgrading some waterfront sites outside the inner harbour for alongside berthing should be kept under review.

According to Wan (2009), MSO will fade out if unfavourable conditions continue. First, Victoria Harbour is becoming narrower. Hence, the future of PCWAs operating on its shores must be reassessed (Dufour et al., 2009). Currently, mid-stream vessels are becoming either too deep-draughted or too long. If this trend continues, we predict that it will strain the capacity of the anchorages. MSO fundamentally benefits from smaller ships (i.e. 3500 TEUs or below) (Loughlin and Pannell, 2010). To improve productivity at anchorages and ease congestion problem, the government has implemented a series of measures, such as reviewing charges to encourage faster turnaround and discourage non-cargo-working activity at the sites closest to mid-stream sites [GHK (Hong Kong) Ltd., 2004; Dufour et al., 2009]. If MSO is to survive as a viable operational model, we recommend associating it with mainland Chinese businesses or moving it to another country.

Second, MSO has faced a serious problem of extortion and thievery in the early stages of operation. This has led the government to discourage the further development of the MSO industry (Dufour et al., 2009). Third, the government has adopted a more favourable policy towards the container terminals, subsidising their operations, while imposing stricter licencing and labour requirements and restrictive financial conditions on MSO. Thus, the number of mid-stream operators has dropped
significantly in recent years (only three large operators with direct land bases remain in regular operation) (Fu et al., 2010). Fourth, the government needs to attract shipping lines and their cargo to Hong Kong. Otherwise, MSO only competes with container terminals and the River Trade Terminal in a diminishing shipping market. Fifth, MSO and PCWA workers are unskilled and not well educated; they are unable to seek alternative work in other trades (Wong, 2012). Education and training will be a key issue for MSO in the future. The National 13th Five-Year Plan and the Belt and Road Initiative highlighted that education and training can foster manpower development to sustain the growth of different maritime sectors (HKSAR Legco, 2017). Comprehensive maritime education and training would upgrade skills and knowledge for the remainder of one’s working life (Lau and Ng, 2015). It would also improve the competitiveness of Hong Kong’s maritime industry and boost Hong Kong’s position as a regional maritime hub. However, it is not obvious that academic institutions offer professional education programmes are relevant with MSO. A shortage of skilled labour still exists in MSO.

5. Conclusion
MSO represents the evolution of Hong Kong’s maritime industrial development since the 1960s. The appearance of MSO diversified the shipping market segment of Hong Kong maritime industry; MSO was fundamental to establishing the maritime industry in Hong Kong, and it solidified Hong Kong as a trade centre in the Asia-Pacific region. When container terminals are well developed in PRD, the enlargement of container terminal capacity induces much less needs for MSO. Nevertheless, the interviewees point out that the government has not taken a proactive role in supporting MSO due to a poor financial return. What will be the fate of MSO? The decline of MSO is unavoidable in the forthcoming years. In the coming years, the interviewees indicate that MSO will face unfavourable conditions, including strong competitors, unstable sea condition that affected cargo handling, reduced a number of cargo barges, a lack of skilled labour, a waterfront shortage, increased capital intensity, competition with direct international sailing from PRD ports and longer distances between the waterfront and the anchorage area. These conditions will lead to MSO’s gradual decline in the maritime industry. In the past 10 years, the introduction of an open auction process to allocate PCWA berths has significantly increased operating costs for both PCWA and MSO operators. Consequently, the weaker existing players will be phased out and the stronger operators will dominate the market. To cope with the shortcomings, the interviewees proposed that:

- opening up more anchorages for specialised cargo, such as Junk Bay, Sham Shui Kok and Causeway Bay (after withdrawal of buoys). These anchorages are geographically located in a more sheltered area which is ideal for specialised or project cargo;
- revising labour policy;
- avoiding accidents and enhance maritime safety standards;
- allocating more PCWAs and expanding waterfront area (barge berth); and
- maintaining marine traffic control over the usage of space in the harbour.

Because cost figures and relevant data are commercial secret, it is difficult for researchers to collect data from maritime stakeholders and published materials.
However, we undertake a small scale of qualitative study by interviewing seven participants in the maritime industry. Their insights can generate a useful reference for maritime industry to review MSO’s position in the Far East. To a certain extent, MSO creates a foundation of Hong Kong maritime industry and diversifies the coverage of maritime service. This preliminary study provides a possible research work in the future. How do the business leaders transform the culture and business models of MSO? How to establish a sound safety management in MSO? These research studies can fill in the previous research gap in maritime studies.

References


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