OPTIMAL INVESTMENT STRATEGY IN A CONTAINER TERMINAL: GAME THEORY APPROACH

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ABSTRACT

This paper investigates the optimal strategy for resource allocation used by port authorities and container terminal operators to attract more carriers. A mathematical model is formulated to represent the main criteria used by carriers to evaluate a specific port. Then, a game theory approach is used to model the competition between several port authorities or operators to attract carriers via maximizing their utility functions. The game type suggested is Sealed- Bid with one round. The results indicate that the optimal investment strategy used by a specific port is dependent on (i) the port's current position, (ii) resource availability, (iii) expected profitability and (iv) other players' reaction toward investment. This study advises the port authority or operator on maximizing the payoff in case of winning the bid and minimizing the loss incurred due to investment in case of losing the bid.

Keywords: Carrier, Container Terminal, Game Theory, Investment Strategy, Port Authority.

INTRODUCTION: MARITIME TRADE

The expansion of international trade was a crucial factor in the growth of the maritime transport during the last few decades. The concept of globalization in addition to potential efficiencies through consolidation has increased the investments of shipping companies in container vessels, and to some extent in container terminals, in order to sustain their current market shares and to secure new markets (Nehme and Awad, 2010; Van de Voorde, 2005).
With the growth of the world container port throughput by 12.1% from 2006 to reach 487 million Twenty-foot Equivalent Units (TEU) in 2007, according to United Nations Conference for Trade and Development (UNCTAD), operators of ports all around the world sought to sustain their container traffic growth by optimizing the use of their resources (UNCTAD, 2008). Even with the worldwide financial crisis that started in summer 2008, the container port throughput increased by 4.5% to reach 509 million TEU in 2008 (UNCTAD, 2008), but decreased to 466 million TEU in 2009 (UNCTAD, 2009). In 2010, container port throughput accomplished an unexpected recovery with an increase of 12.9% to reach 526 million TEU and in 2011 container port throughput increased to 580 million TEU (UNCTAD, 2011).

In this paper, the optimal investment strategy by the port authority or container terminal operator (CTO) is investigated based on a game theory approach that takes into account a number of port selection criteria by carriers. The methodology suggested in this study is to develop a utility function that represents carrier preference for a specific port, and then maximize the utility subject to financial, physical, and location constraints.

This paper is structured as follows. Section 2 presents a brief review of relevant literature related to port selection and competition from strategic perspective. Section 3 discusses the mathematical model formulated. Section 4 illustrates the game theory process. Section 5 discusses the observations related to the formulated model. Section 6 summarizes the paper and proposes future research.

LITERATURE REVIEW

In this section, research related to port selection and competition is briefly discussed then research related to modeling port competition using game theory is briefly investigated.

Several studies evaluated criteria in the carriers' port selection decisions (Baird, 2000; Fleming and Baird, 1999; Frankel, 1992; Hayuth, 1995; Murphy et al., 1989; Porcari, 1999; Slack, 1985; Ugboma et al., 2006). Lirn et al. (2003) studied the port selection decision by analyzing data collected from a field survey performed in Taiwan. The authors presented six major criteria for port selection from carrier's perspective in the port selection in Taiwan: (1) water depth of port, (2) marshalling yard, (3) basic cargo volume, (4) geographical advantage, (5) port efficiency and (6) cost of container- handling for carriers.

Lirn et al. (2004) extended the work of Lirn et al. (2003) to identify four main criteria embracing twelve sub-criteria for port selection globally defined as follow:

First Criterion: Port Physical and Technical Infrastructure. This criterion includes three sub-criteria (1) basic infrastructure condition such as water access and depth of port, (2) technical structure such available number of berths, port equipment and back–up space on terminal, and (3) intermodal links such as size of port terminal capacity, port accessibility and port service coverage.

Second Criterion: Port Geographical Location. This criterion includes three sub-criteria (1) proximity to import and export areas, (2) proximity to feeder ports, and (3) proximity to main navigation routes.

Third Criterion: Port Management and Administration. This criterion includes three sub-criteria (1) management and administration efficiency, (2) vessel turn-around time and (3) port security and safety.

Fourth Criterion: Carriers' Terminal Cost. This criterion includes three sub-criteria (1) handling cost of containers, (2) storage costs of containers and (3) terminal ownership exclusive contract policy.

The methodology used by Lirn et al. (2004) consists of an analytic hierarchy process (AHP) questionnaire survey that was filled by 20 port users and 20 transshipment service providers distributed all over the world in order to determine the extent of impact for each main criterion.

As for the port competition, from a game theory approach, Anderson et al. (2008) proposed a Nash Equilibrium of a Bertrand pricing game to analyze competition between two ports based on expansion strategy, i.e., invest or do not invest, in order to attract more cargo. The study considered competition between the ports of Busan and Shanghai in Asia. Pricing was based on a combination of perfect competition and oligopolistic imperfect competition.

Saeed and Larsen (2010) presented a Bertrand game of competition between four container terminals in two ports via a two stage model where the first stage was to decide on the level of coalition between three container terminals in the same port and the second stage was the competition between the two ports based on the first stage results. The authors determined the net effect on the profits of all players for all possible scenarios. The study revealed that the highest benefit for all players is the grand coalition, when all players are members of the coalition.

In this research, we contribute to the literature by formulating a game theory framework for port's strategic investment to attract more carriers based on the four main criteria identified by Lirn et al. (2004). We formulate a mathematical model to represent factors related to attracting carriers taking into consideration the existence of competition among ports. This contribution is vital to understand the strategic investments in ports.

MATHEMATICAL MODEL

Based on the four criteria defined by Lirn et al. (2004), a utility function for port selection from the carrier's perspective is formulated. The four criteria are: (1) Port Physical and Technical Infrastructure, (2) Port Geographical Location, (3) Port Management and Administration and (4) Carriers' Terminal Cost.

In this section, the utility functions used for port selection from both revenue and cost perspectives are defined. Then, the constraints that bound the port investments are identified.

Utility Functions

The attractiveness for a carrier to select a specific port i is defined to be:

$$u_i = w_1 a_i + w_2 b_i + w_3 c_i + w_4 d_i \qquad \text{Equation (1)}$$

Where:

- w_1 is the weight for the technical infrastructure criterion
- a_i is the score on Likert scale (from 1 to 5, 1 = lowest scale and 5 = highest scale) for port i with respect to the technical infrastructure criterion
- w_2 is the weight for geographical location criterion
- b_i is the score on Likert scale (from 1 to 5, 1 = lowest scale and 5 = highest scale) for port i with respect to the port geographical criterion
- w_3 is the weight for the port management and administration criterion
- c_i is the score on Likert scale (from 1 to 5, 1 = lowest scale and 5 = highest scale) for port i with respect to the port management and administration criterion
- w_4 is the weight for the carrier's terminal cost criterion
- d_i is the score on Likert scale (from 1 to 5, 1 = lowest scale and 5 = highest scale) for port i with respect to the carrier's terminal cost criterion

Since the summation of weights should be equal to 1, then

$w_1 + w_2 + w_3 + w_4 = 1$ Equation (2)

The values of w_1, w_2, w_3, and w_4 are adopted from the study conducted by Lirn et al. (2004). Therefore, $w_1 = 16.38\%$, $w_2 = 35.12\%$, $w_3 = 10.38\%$ and $w_4 = 38.12\%$.

The utility of a carrier, assuming a rational behavior, to choose a specific port *i* among a set of ports *N* is $V = \max_{i \in N} u_i$ Equation (3)

Equations (1) and (3) are easily solved if the competition to attract carriers among ports is ignored. However, this competition exists. Every port *i* is aware of the existence of other ports and seeks to increase its utility function by investing in the port. The investment in ports is translated according to Equation (1) in increasing the value of *a, b, c* and *d* (base or current situation) to $a + \Delta a$, $b + \Delta b$, $c + \Delta c$, and $d + \Delta d$ (after investment). Thus, Equation (1) becomes

$u_i = w_1(a + \Delta a) + w_2(b + \Delta b) + w_3(c + \Delta c) + w_4(d + \Delta d)$ Equation (4)

The new attributes $a + \Delta a$, $b + \Delta b$, $c + \Delta c$, and $d + \Delta d$ have enhancement boundaries such that

Upper Bound Condition: the maximum scale achieved on Likert scale is 5, the port has limitation on the level of enhancement.

$a + \Delta a, b + \Delta b, c + \Delta c, d + \Delta d \leq 5$ for every port *i* Equation (5)

Lower Bound Condition: After any investment, if any, the the “after investment situation” of a specific port should not be less than base or current situation .

$\Delta a, \Delta b, \Delta c, \Delta d \geq 0$ for every port *i* Equation (6)

Payoff for Port

Every variation in the criteria due to investment leads to additional cost $C(\Delta a, \Delta b, \Delta c, \Delta d)$ for the port. As such the payoff function for a specific port *i* is

$\pi_i = P_i . I_i - C(\Delta a_i, \Delta b_i, \Delta c_i, \Delta d_i)$ Equation (7)

Where

- P_i is the revenue generated by a port *i* when the carrier chooses the specific port *i.*
  The revenue generated by port is affected by (1) the port operation costs, (2) the size of the carrier, and (3) the agreement made with the carrier. The utility function of the revenue is defined in the next sub-section.
- I_i is a binary variable such that $I_i = \begin{cases} 1 \ if \ port \ i \ is \ selected \ by \ the \ carrier \\ 0 \ otherwise \end{cases}$
  Since we are considering that the carrier will select only one port from a set of ports *N*, then
  $\sum_{i \in N} I_i = 1$ Equation (8)
- $C(\Delta a_i, \Delta b_i, \Delta c_i, \Delta d_i)$ is the cost function incurred due to port investment in the four criteria to compete with other ports in attracting the carrier.

Revenue Function

In developing the revenue function generated from investing in the port, we assume that the function shall have diseconomies of scale based on diminishing marginal productivity. These assumptions are reasonable due to the large scale investment required for port development which is likely to entail some losses in efficiency when increasing the inputs as discussed by

"Adam Smith" in analyzing the production of pins (Snyder and Nicholson, 2008). These assumptions are supported by Haralambides (2002) for applications related to ports. The author discussed the case where the port is faced with a situation where the demand for its services is higher than its handling capacity which leads to over utilization of port capacity, more accidents in cargo handling, imposing of surcharges on shippers by carriers and more demurrages claims. In this case, the port incurs diseconomies of scale and has to allocate its scarce resources according to carriers' willingness to pay (Haralambides, 2002).

The initial revenue function for a port *i* is defined as follow:

$$P_i = a_i(1 - e^{-a_i}) + b_i(1 - e^{-b_i}) + c_i(1 - e^{-c_i}) + d_i(1 - e^{-d_i})$$ Equation (9)

This revenue function is the current payoff function before any investment in any criterion in the four mentioned criteria.

The revenue function for a port *i* after investment is:

$$P_i = (a_i + \Delta a_i)(1 - e^{-(a_i+\Delta a_i)}) + (b_i + \Delta b_i)(1 - e^{-(b_i+\Delta b_i)}) + (c_i + \Delta c_i)(1 - e^{-(c_i+\Delta c_i)}) + (d_i + \Delta d_i)(1 - e^{-(d_i+\Delta d_i)})$$

Equation (10)

Cost Function

The cost function is defined as follow:

$$C(\Delta a_i, \Delta b_i, \Delta c_i, \Delta d_i) = a_i * \Delta a_i^{\Delta a_i} + b_i * \Delta b_i^{\Delta b_i} + c_i * \Delta c_i^{\Delta c_i} + d_i * \Delta d_i^{\Delta d_i}$$ Equation (11)

In the absence of any increase (investment) in a specific attribute, the term of the attribute becomes zero. For instance if Δa_i and Δb_i are zero Equation (11) becomes

$$C(\Delta a_i, \Delta b_i, \Delta c_i, \Delta d_i) = c_i * \Delta c_i^{\Delta c_i} + d_i * \Delta d_i^{\Delta d_i}$$

Constraints

In this sub-section, the financial, physical and location constraints that limit the investment in the port are discussed

Budget Constraint

There is a budget constraint that restricts the "investment" for every port *i* based on fund availability such that: $\Delta a_i + \Delta b_i + \Delta c_i + \Delta d_i \leq budget_i$ Equation (12)

Capacity Constraint

Every port *i* has a capacity constraint due to physical infrastructure capacity of the port

$$\Delta a_i \leq capacity_i$$ Equation (13)

Location Constraint

Unless the port operator can shift location of the port, no investment could be done for the attribute of "Port Geographical Location", thus $\Delta b_i = 0$ Equation (14)

Manpower Constraint

The enhancement of (i) management efficiency, (ii) vessel turn-around and (iii) port security and safety is restricted by the availability of manpower resources.

$\Delta c_i \leq manpower_i$ Equation (15)

Price Constraint

Every port *i* has its own price policy that could not be altered drastically, especially regarding handling cost and storage cost of containers.

$\Delta d_i \leq price_i$ Equation (16)

GAME THEORY PROCESS

In this section, the game theory process is illustrated. First, the game type suggested in this research is presented. Then, a numerical example is presented to illustrate the game process.

Game Type

The proposed methodology suggested in this part of the paper is modeling the port selection process using game theory approach. The game type suggested is a first-price sealed-bid auction. The set of actions of each player is the set of possible bids (Osborne, 2009).
In this study the term player refers to port authority or port operator in charge of the potential investment in the four criteria previously mentioned. The bid term refers to investment made. The objective of the player is to maximize the utility function from the carrier's perspective to "win" the bid.
The assumptions made here are:

- Every player has perfect and complete information about other players. In this case, each player knows the set of available choices for him and for the other players, the payoff functions of each possible choice made or strategy pursued by him or by the other players, and is aware that other players have complete information about him (Osborne, 2009).
- Factor of Time and number of rounds: 1 round only (Sealed-Bid).

The game theory process is further explained via a numerical illustration.

Numerical Illustration

Consider 2 different ports as follows.

Port 1 Characteristics

Port 1 has scored: 3 over 5 for the first criterion "Port Physical and Technical Infrastructure" a_1 = 3, 4 over 5 for the second criterion "Port Geographical Location" b_1 = 4, 3 over 5 for the third criterion "Port Management and Administration" c_1 = 3, and 3 over 5 for the fourth criterion "Carriers' Terminal Cost" d_1 = 3. The current attractiveness of Port 1 to a specific carrier is $u_1 = 3.35$.

The constraints for Port 1 are as follows:

- Budget Constraint: Port 1 has a fund availability of 5 units. $\Delta a_1 + \Delta b_1 + \Delta c_1 + \Delta d_1 \leq 5$.
- Capacity Constraint: Port 1 may enhance its technical infrastructure by 2 units. $\Delta a_1 \leq 2$.
- Location Constraint: Port 1 is restricted by the geographical location; the location in this case cannot be enhanced. $\Delta b_1 = 0$.
- Manpower Constraint: Port 1 may enhance its management and administration by investing 2 units in its manpower. $\Delta c_1 \leq 2$.
- Price Constraint: Port 1 may enhance the fourth criterion by reducing its price to the carrier by 1 unit. $\Delta d_1 \leq 1$.

In this case Port 1 has 18 options to consider for investment.

Table 1 represents all the possible investments in the first five columns, the attractiveness utility of each port for the carrier in column 6, revenue generated in case of attracting the carrier in column 7, cost of investment in column 8, and payoff generated (revenue – cost) in column 9 for Port 1.

Table 1- Possible Investment Scenario for Port 1

	a	b	c	d	u_1	Revenue	Cost	Payoff
Investment	**3**	**4**	**3**	**3**	**3.35**	**12.48**	**0**	**12.48**
(0,0,0,0)	0	0	0	0	3.35	12.48	0	12.48
(0,0,0,1)	0	0	0	1	3.73	13.55	3	10.55
(0,0,1,0)	0	0	1	0	3.46	13.55	3	10.55
(0,0,1,1)	0	0	1	1	3.84	14.63	6	8.63
(0,0,2,0)	0	0	2	0	3.56	14.59	12	2.59
(0,0,2,1)	0	0	2	1	3.94	15.67	15	0.67
(1,0,0,0)	1	0	0	0	3.52	13.55	3	10.55
(1,0,0,1)	1	0	0	1	3.90	14.63	6	8.63
(1,0,1,0)	1	0	1	0	3.62	14.63	6	8.63
(1,0,1,1)	1	0	1	1	4.00	15.71	9	6.71
(1,0,2,0)	1	0	2	0	3.72	15.67	15	0.67
(1,0,2,1)	1	0	2	1	4.10	16.75	18	-1.25
(2,0,0,0)	2	0	0	0	3.68	14.59	12	2.59
(2,0,0,1)	2	0	0	1	4.06	15.67	15	0.67
(2,0,1,0)	2	0	1	0	3.78	15.67	15	0.67
(2,0,1,1)	2	0	1	1	4.16	16.75	18	-1.25
(2,0,2,0)	2	0	2	0	3.89	16.71	24	-7.29
(2,0,2,1)	2	0	2	1	4.27	17.79	27	-9.21

Port 2 Characteristics

Port 2 has scored: 2 over 5 for the first criterion “Port Physical and Technical Infrastructure” $a_2 = 2$, 3 over 5 for the second criterion “Port Geographical Location” $b_2 = 3$, 3 over 5 for the third criterion “Port Management and Administration” $c_2 = 3$, and 5 over 5 for the fourth criterion “Carriers’ Terminal Cost” $d_2 = 5$. The current attractiveness of Port 2 to a specific carrier is $u_2 = 3.60$.

The constraints for Port 2 are as follows:

- Budget Constraint: Port 2 has a fund availability of 5 units. $\Delta a_2 + \Delta b_2 + \Delta c_2 + \Delta d_2 \leq 3$.
- Capacity Constraint: Port 2 may enhance its technical infrastructure by 2 units. $\Delta a_2 \leq 2$.
- Location Constraint: Port 2 is restricted by the geographical location; the location in this case cannot be enhanced. $\Delta b_2 = 0$.
- Manpower Constraint: Port 2 may enhance its management and administration by investing 2 units in its manpower. $\Delta c_2 \leq 1$.
- Price Constraint: Port 2 may enhance the fourth criterion by reducing its price to the carrier by 1 unit $\Delta d_2 \leq 1$. Or since already Port 2 scored 5 over 5 on this criterion, any reduction of price (enhancing the score of d_2) is redundant. Thus, $\Delta d_2 = 0$.

In this case Port 2 has 8 options to consider for investment. Table 2 represents all the possible investments in the first five columns, the attractiveness utility of each port for the carrier in column 6, revenue generated in case of attracting the carrier in column 7, cost of investment in column 8, and payoff generated (revenue – cost) in column 9 for Port 2.

Table 2 - Possible Investment Scenario for Port 2

	a	**b**	**c**	**d**	**u_2**	**Revenue**	**Cost**	**Payoff**
Investment	**2**	**3**	**3**	**5**	**3.60**	**12.40**	**0**	**12.40**
(0,0,0,0)	0	0	0	0	3.60	12.40	0	12.40
(0,0,1,0)	0	0	1	0	3.70	13.47	3	10.47
(0,0,2,0)	0	0	2	0	3.81	14.51	12	2.51
(1,0,0,0)	1	0	0	0	3.76	13.52	2	11.52
(1,0,1,0)	1	0	1	0	3.87	14.59	5	9.59
(1,0,2,0)	1	0	2	0	3.97	15.63	14	1.63
(2,0,0,0)	2	0	0	0	3.93	14.59	8	6.59
(2,0,1,0)	2	0	1	0	4.03	15.67	11	4.67

Game Process

In this case, 18 possible investment options for Port 1 and 8 possible investment options for Port 2 are considered. In order to understand the reaction of players toward every possible investment, evaluation of each possible investment option of player 1 (Port 1) with all possible investment option of player 2 (Port 2) is needed. Hence, 144 possible scenarios are considered for evaluation. Table 3 tabulates which port will win the bid for potential investment option, based on the highest attractiveness utility of carrier as per Equation (3). Table 4 tabulates the payoff for every investment for Port 1 and Port 2 for every potential investment option as per Equation (7).

Table 3 - Bidding Award for Every Potential Investment Option

		PORT 2							
		(0,0,0,0)	(0,0,1,0)	(0,0,2,0)	(1,0,0,0)	(1,0,1,0)	(1,0,2,0)	(2,0,0,0)	(2,0,1,0)
PORT 1	(0,0,0,0)	Port 2	Port 2	Port 2	Port 2	Port 2	Port 2	Port 2	Port 2
	(0,0,0,1)	Port 1	Port 1	Port 2	Port 2	Port 2	Port 2	Port 2	Port 2
	(0,0,1,0)	Port 2	Port 2	Port 2	Port 2	Port 2	Port 2	Port 2	Port 2
	(0,0,1,1)	Port 1	Port 1	Port 1	Port 1	Port 2	Port 2	Port 2	Port 2
	(0,0,2,0)	Port 2	Port 2	Port 2	Port 2	Port 2	Port 2	Port 2	Port 2
	(0,0,2,1)	Port 1	Port 1	Port 1	Port 1	Port 1	Port 2	Port 1	Port 2
	(1,0,0,0)	Port 2	Port 2	Port 2	Port 2	Port 2	Port 2	Port 2	Port 2
	(1,0,0,1)	Port 1	Port 1	Port 1	Port 1	Port 1	Port 2	Port 2	Port 2
	(1,0,1,0)	Port 1	Port 2	Port 2	Port 2	Port 2	Port 2	Port 2	Port 2
	(1,0,1,1)	Port 1	Port 1	Port 1	Port 1	Port 1	Port 1	Port 1	Port 2
	(1,0,2,0)	Port 1	Port 1	Port 2	Port 2	Port 2	Port 2	Port 2	Port 2
	(1,0,2,1)	Port 1	Port 1	Port 1	Port 1	Port 1	Port 1	Port 1	Port 1
	(2,0,0,0)	Port 1	Port 2	Port 2	Port 2	Port 2	Port 2	Port 2	Port 2
	(2,0,0,1)	Port 1	Port 1	Port 1	Port 1	Port 1	Port 1	Port 1	Port 1
	(2,0,1,0)	Port 1	Port 1	Port 2	Port 1	Port 2	Port 2	Port 2	Port 2
	(2,0,1,1)	Port 1	Port 1	Port 1	Port 1	Port 1	Port 1	Port 1	Port 1
	(2,0,2,0)	Port 1	Port 1	Port 1	Port 1	Port 1	Port 2	Port 2	Port 2
	(2,0,2,1)	Port 1	Port 1	Port 1	Port 1	Port 1	Port 1	Port 1	Port 1

Table 4 - Payoff for Every Potential Investment Option

		PORT 2															
		(0,0,0,0)		(0,0,1,0)		(0,0,2,0)		(1,0,0,0)		(1,0,1,0)		(1,0,2,0)		(2,0,0,0)		(2,0,1,0)	
PORT 1	(0,0,0,0)	0.00	12.40	0.00	10.47	0.00	2.51	0.00	11.52	0.00	9.59	0.00	9.59	0.00	1.63	0.00	6.59
	(0,0,0,1)	10.55	0.00	10.55	-3.00	-3.00	2.51	-3.00	11.52	-3.00	9.59	-3.00	9.59	-3.00	1.63	-3.00	6.59
	(0,0,1,0)	-3.00	12.40	-3.00	10.47	-3.00	2.51	-3.00	11.52	-3.00	9.59	-3.00	9.59	-3.00	1.63	-3.00	6.59
	(0,0,1,1)	8.63	0.00	8.63	-3.00	8.63	-12.00	8.63	-2.00	-6.00	9.59	-6.00	9.59	-6.00	1.63	-6.00	6.59
	(0,0,2,0)	-12.00	12.40	-12.00	10.47	-12.00	2.51	-12.00	11.52	-12.00	9.59	-12.00	9.59	-12.00	1.63	-12.00	6.59
	(0,0,2,1)	0.67	0.00	0.67	-3.00	0.67	-12.00	0.67	-2.00	0.67	-5.00	-15.00	9.59	0.67	-14.00	-15.00	6.59
	(1,0,0,0)	-3.00	12.40	-3.00	10.47	-3.00	2.51	-3.00	11.52	-3.00	9.59	-3.00	9.59	-3.00	1.63	-3.00	6.59
	(1,0,0,1)	8.63	0.00	8.63	-3.00	8.63	-12.00	8.63	-2.00	8.63	-5.00	-6.00	9.59	-6.00	1.63	-6.00	6.59
	(1,0,1,0)	8.63	0.00	-6.00	10.47	-6.00	2.51	-6.00	11.52	-6.00	9.59	-6.00	9.59	-6.00	1.63	-6.00	6.59
	(1,0,1,1)	6.71	0.00	6.71	-3.00	6.71	-12.00	6.71	-2.00	6.71	-5.00	6.71	-5.00	6.71	-14.00	-9.00	6.59
	(1,0,2,0)	0.67	0.00	0.67	-3.00	-15.00	2.51	-15.00	11.52	-15.00	9.59	-15.00	9.59	-15.00	1.63	-15.00	6.59
	(1,0,2,1)	-1.25	0.00	-1.25	-3.00	-1.25	-12.00	-1.25	-2.00	-1.25	-5.00	-1.25	-5.00	-1.25	-14.00	-1.25	-8.00
	(2,0,0,0)	2.59	0.00	-12.00	10.47	-12.00	2.51	-12.00	11.52	-12.00	9.59	-12.00	9.59	-12.00	1.63	-12.00	6.59
	(2,0,0,1)	0.67	0.00	0.67	-3.00	0.67	-12.00	0.67	-2.00	0.67	-5.00	0.67	-5.00	0.67	-14.00	0.67	-8.00
	(2,0,1,0)	0.67	0.00	0.67	-3.00	-15.00	2.51	0.67	-2.00	-15.00	9.59	-15.00	9.59	-15.00	1.63	-15.00	6.59
	(2,0,1,1)	-1.25	0.00	-1.25	-3.00	-1.25	-12.00	-1.25	-2.00	-1.25	-5.00	-1.25	-5.00	-1.25	-14.00	-1.25	-8.00
	(2,0,2,0)	-7.29	0.00	-7.29	-3.00	-7.29	-12.00	-7.29	-2.00	-7.29	-5.00	-24.00	9.59	-24.00	1.63	-24.00	6.59
	(2,0,2,1)	-9.21	0.00	-9.21	-3.00	-9.21	-12.00	-9.21	-2.00	-9.21	-5.00	-9.21	-5.00	-9.21	-14.00	-9.21	-8.00

ANALYSIS AND DISCUSSION

From table 3, we can deduce that for investment options (1, 0, 2, 1), (2, 0, 0, 1), (2, 0, 1, 1) and (2, 0, 2, 1) Port 1 has a strictly dominant solution; Port 2 has no dominant solution. All the other investment options are weakly dominant solutions for both Port 1 and Port 2. The dominant solutions for Port 1 (1, 0, 2, 1), (2, 0, 0, 1), (2, 0, 1, 1) and (2, 0, 2, 1) reveal that Port 1 will attract the carrier, regardless of the reaction of Port 2, in case of applying any of the mentioned investment strategy.

From table 4, we notice that the payoff of investment strategy (1, 0, 2, 1) for Port 1 will generate a loss of 1.25, the investment strategy (2, 0, 0, 1) will generate a very minimal payoff of 0.67, the investment strategy (2, 0, 1, 1) will generate a loss of 1.25, and the investment strategy (2, 0, 2, 1) for Port 1 will generate a loss of 9.21. The above reveals that even if an investment strategy will attract the carrier, the port authority should make sure that the cost of investment will not exceed the revenue generated from the business of the new carrier; otherwise the port's payoff will not be profitable.

Tables 3 and 4 are tools to assist the port authority to make decision regarding the best investment strategy to use taking into consideration the other competitor reaction toward this investment.

The presented approach in this paper provides a managerial tool for port authorities around the world to allocate their investments in the optimal manner with the objective of better positioning their port to attract carriers.

Using this game theory approach, a port authority is able to identify its target, which is the carrier, and its other competitors. The port authority, based on the utility function developed, is able to assess its weaknesses and strengths, in addition to weaknesses and strengths of other port competitors. In this model, the reaction of other players in the market is presented taking into consideration financial, physical, and location constraints. The port authority shall consider the existence of competition in any future investment strategy to enhance its ability to attract carriers, which is reflected in maximizing its utility function to attract carriers and minimizing losses in case of inability to attract carriers from competitors.

More in depth analysis is being conducted currently to reveal some managerial insights related to the investment strategy policy recommended to ports based on the above developed model and equations.

SUMMARY AND FUTURE RESEARCH

In this paper, we study the optimization of resource deployment in a container terminal from a strategic perspective. A mathematical model is formulated to represent the main criteria used by carriers to evaluate a specific port. Then, a game theory approach is used to model the competition between several port authorities or operators in attracting carriers via maximizing their utility functions. The game type suggested is Bidding/Auction via Sealed- Bid or First Price Auction. In this game, the assumptions made are (i) every player has perfect and complete information about other players and the set of available choices, and (ii) the game consists of one round only (Sealed-Bid). The results indicate that the optimal investment strategy used by a specific port is unique and dependent on (i) the port's current position, (ii) resource availability, (iii) expected profitability and (iv) other players' reactions toward investment. This study models the rules for investment inside the port. The rules maximize the payoff for a port authority or operator in case of winning the bid and minimize the loss incurred due to investment implementation in case of losing the bid.

This study (i) provides a framework for prioritizing investments by ports based on criteria used by customers (carriers) in port selection and (ii) considers the reaction of other competitor ports toward their expansion and investments.

The formulated model assumes complete and perfect information among players. Considering incomplete and imperfect information among players is a possible interest for future research. The quality of information in the incomplete and imperfect situations can be assessed in terms of cost paid to enhance the quality of information about competitors. The work performed by Yassine et al. (2013) regarding the optimal information exchange can be integrated to estimate the cost of information in mitigating risks in port investment.

Coalition among different terminal operators to minimize investment cost and avoid competition in attracting carriers is another potential research area. Another possible direction in our future research is to consider the impact of optimization at the operational level, especially the integration between different types of resources at the container terminal (Kaysi et al., 2012), on tailoring the optimal investment strategy in a container terminal.

REFERENCES

Anderson, C.M., Park, Y.A., Chang, Y.T.; Yang, C.H., Lee, T.W. and Luo, M. (2008). A game-theoretic analysis of competition among container port hubs: The case of Busan and Shanghai. Maritime Policy and Management, 35, 5-26.

Baird, A.J. (2000). Port privatization: Objectives, extent, process and the UK experience, International. Journal of Maritime Economics, 2, 177-194.

Fleming, D.K.; and Baird, A.J.(1999). Some reflections on port competition in the United States and Western Europe. Maritime Policy and Management, 26, 383-394.

Frankel, E.G. (1992). Hierarchical logic in shipping policy and decision-making. Maritime Policy and Management, 19, 211-221.

Haralambides, H. (2002). Competition, Excess Capacity, and the Pricing of Port Infrastructure. International Journal of Maritime Economics, 4, 323-347.

Hayuth, Y. (1995). Container traffic in ocean shipping policy. Proceedings of the International Conference Ports for Europe.

Kaysi, I.A., Maddah, B., Nehme, N. and Mneimneh, F. (2012). An Integrated Model for Resource Allocation and Scheduling in a Transshipment Container Terminal. Transportation Letters: The International Journal of Transportation Research, 4, 143-152.

Lirn, T.C., Thanopoulou, H.A. and Beresford, A.K.C. (2003).Transshipment Port Selection and Decision-making Behavior: Analysing the Taiwanese Case. International Journal of Logistics: Research and Application, 6, 229-241.

Lirn, T.C., Thanopoulou, H.A., Beynon, M.J. and Beresford, A.K.C. (2004). An Application of AHP on Transshipment Port Selection: A Global Perspective. Maritime Economics & Logistics, 6, 70-91.

Murphy, P. R.; Dalenburg, D. R. and Daley, J.M. (1989). Assessing international port operations. International Journal of Physical Distribution and Logistics Management, 19, 3-10.

Nehme, N. and Awad, M. (2010). A Pseudo Bargaining Formulation for Servicing Vessels during Transshipment Operations. Proceedings of the International Conference on Information & Knowledge Engineering, 231-237.

Osborne, O. (2009). An Introduction to Game Theory. Oxford University Press.

Porcari, J.D. (1999). The logical choice for a Northeast hub. Journal of Commerce.

Ugboma, C., Ugboma, O., and Ogwude, I.C. (2006). An Analytic Hierarchy Process (AHP) Approach to Port Selection Decision – Empirical Evidence from Nigeria Ports. Maritime Economics and Logistics, 8, 251-266.

UNCTAD. (2008).Review of Maritime Transport 2008, United Nations Conference on Trade and Development, New York and Geneva.

UNCTAD. (2009). Review of Maritime Transport, 2009, United Nations Conference on Trade and Development, New York and Geneva.

UNCTAD. (2011). Review of Maritime Transport, 2011, United Nations Conference on Trade and Development, New York and Geneva.

Saeed, N. and Larsen, O.I. (2010). An application of cooperative game among container terminals of one port. European Journal of Operational Research, 203, 393-403.

Slack, B. (1985). Containerization. Inter-port competition and port selection. Maritime Policy and Management, 12, 293-303.

Snyder, C. and Nicholson, W. (2008). Microeconomic Theory: Basic Principles and Extensions. South –Western Cengage Learning.

Van de Voorde, E.E.M (2005). What Future the Maritime Sector: Some Considerations on Globalisation, Co-Operation and Market Power. Research in Transportation Economics, 13, 253-277.

Yassine, A., Maddah, B. and Nehme, N. (2013). Optimal Information Exchange Policies in Integrated Product Development. IIE Transaction, forthcoming.