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A game theory competition analysis of quadropolistic liner container shipping market

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Abstract

This paper demonstrates a non-cooperative four rational player's static game framework to analyse the shipping alliance competition on a particular Far East-Northern Europe liner shipping service loop. The complete-perfect information case of the players is taken into account and the Cournot-Nash equilibrium pure strategy solution concept is utilised. The approach developed in this study focuses on the current liner shipping alliance structure and assumes the long term stability of the current alliances. The research steps are mathematically integrated to different methodological outcomes and numerically tested in the given case study. The results suggested that, in a two year period, additional ship capacity deployment would reduce the competitiveness of the alliances. It is proposed that outcomes of this research will provide significant theoretical contribution to the existing literature and will generate a robust tactical decision support rationale regarding to the capacity deployment problem of the liner container shipping industry.

Keywords: Shipping Alliances, Cournot Oligopoly, Liner Shipping, Competition Analysis, Capacity Deployment

1. Introduction

The liner container shipping industry plays a critical role in the viability of the international trade. Therefore, the market behaviours and allocation of the liner shipping services is a great interest of the global trade actors. Historically, the liner container shipping market was controlled by conference monopolies until the anti-trust legal enforcements ended their cartels. A very long period of time, the shipping liners had been exempted from anti-trust legislations of the trade law and freight rate fixing were allowed. In 1990s the freight rate fixing was banned and the liner shipping conferences were replaced by the shipping alliances which have been established to respond the requirements of slot chartering, sharing capital investment risks, improvement of the network coverage, and support of strategic operational and management decisions among cooperative competitor container shipping liners (UNCTAD, 2014; Shi and Voss, 2011). The liner shipping alliances utilises strategic decision makings and tactical planning of members in order to gain operational flexibility, sustainability and cost efficiency due to the shared utilisation service capabilities. The liner shipping alliances have experienced competitive developments and evolutions since 1995. In 1998, due to cross-alliance mergers and acquisitions, the form of shipping alliances changed and The New World Alliance replaced Global Alliance (Doi *et al.*, 2000). This trend was spread on other alliances and continued until China's rejection of the Pioneer 3 shipping alliance network. Thus, the shipping liners were enforced to develop new perspectives for their strategic alliances. As shown in the following Table, in 2015 the shipping alliances were shaped as four competitors as a consequence of the rejection of the P3 alliance.

Table.1 Historical development of the shipping alliances

<table>
<tr><th>1995-1996</th><th>1998-2001</th><th>2005-2010</th><th>2010-2013</th><th>2013-2014</th><th>2015-?</th></tr>
<tr><td>Grand

Hapag Lloyd, NOL, NYK, P&O</td><td>Grand

Hapag Lloyd, NOL, NYK, P&O, Nedlloyd, OOCL</td><td>Grand

Hapag Lloyd, CP, NYK, MISC, OOCL</td><td>Grand

Hapag Lloyd, NYK, OOCL</td><td rowspan="2">Grand 6

Hapag Lloyd, NYK, OOCL, MOL, APL, HMM</td><td rowspan="2">Grand 6 (G6)

Hapag Lloyd, NYK, OOCL, MOL, APL, HMM</td></tr>
<tr><td>Global

MOL, APL, Nedlloyd, MISC, OOCL</td><td>The New World

MOL, APL, MISC</td><td>The New World

MOL, APL, HMM</td><td>The New World

MOL, APL, HMM</td></tr>
<tr><td>CKY

Cosco, "K" Line, YML</td><td>CKY

Cosco, "K" Line, YML</td><td rowspan="2">CKYH

Cosco, "K" Line, YML, Hanjin</td><td rowspan="2">CKYH

Cosco, "K" Line, YML, Hanjin</td><td rowspan="3">CKYHE

Cosco, "K" Line, YML, Hanjin, Evergreen</td><td rowspan="3">CKYHE

Cosco, "K" Line, YML, Hanjin, Evergreen</td></tr>
<tr><td>United:

Cho Yang, Hanjin, DSR</td><td>United:

Cho Yang, Hanjin, DSR</td></tr>
<tr><td>Evergreen</td><td>Evergreen</td><td>Evergreen</td><td>Evergreen</td></tr>
<tr><td>Maersk & Sea Line</td><td>Maersk & Sea Line</td><td>Maersk & Sea Line, P&O, Nedlloyd</td><td>APM Maersk</td><td rowspan="3">Pioneer 3

APM Maersk, MSC, CMA CGM</td><td rowspan="2">2M

APM Maersk, MSC</td></tr>
<tr><td>MSC</td><td>MSC</td><td>MSC</td><td>MSC</td></tr>
<tr><td>CMA CGM</td><td>CMA CGM</td><td>CMA CGM</td><td>CMA CGM</td><td rowspan="3">Ocean 3 (O3)

CMA CGM, UASC, CSCL</td></tr>
<tr><td>UASC</td><td>UASC</td><td>UASC</td><td>UASC</td><td>UASC</td></tr>
<tr><td>CSCL</td><td>CSCL</td><td>CSCL</td><td>CSCL</td><td>CSCL</td></tr>
</table>

Source: Adapted from (Panayides and Wiedmar, 2011; Shi and Voss, 2008)

Nowadays, the rationale behind strategic cooperation in the liner container shipping business is efficient capacity utilisation of the fleets owned by individual shipping liners by aiming to prevent the negative impacts of the ship size enlargement trend. The research effort on the capacity deployment is associated with the recent developments of the liner shipping. One of the main obstacles in the liner container shipping industry is the regulatory enforcement of the International Maritime organization (IMO). The energy efficiency, emission, and sustainability regulations of IMO required significant operational effort and investment of the shipping liners in order to reduce greenhouse gas (GHG) emissions, to save energy and to contribute to the marine sustainability. Another obstacle that the industry faces is the overcapacity of ship capacity supply to the market due to the enlargement of the ship size which also causes operational problems for the ports such as draft, handling and port traffic. In addition, instability of bunker prices drives the innovation requirements for energy efficiency of existing marine and structural systems and available bunkering sources. Due to the capacity oversupply, freight rates in low levels and threatens the financial stability of the liner shipping companies. All these obstacles have a huge influence on the liner shipping competition outcomes for global trade and competitiveness level of the players in the liner shipping market.

The present market tolerance is a significant indicator of the optimal ship size determination. Therefore, optimal capacity deployment via optimal average ship size selection needs to maintain the market based perspective of the liner container shipping services. The liner container shipping alliances are established to provide better utilisation of the mega container vessels. However, the additional capacity investment of individual alliance members requires a narrow research focus on their mega vessel newbuilding orders as well as the financial consequences of their capacity deployment decision making rationales.

This paper presents a game theoretical methodology of non-cooperative four rational players' oligopolistic competition in order to adapt to the practical liner service loop cases. The study considers recent four shipping alliances as fully rational heterogeneous players and generates a tactical decision making concept regarding to the capacity deployment of the shipping alliances. In chapter 2, brief literature and milestones of the subject investigated is given. In chapter 3, the methodology of the study is established based on the influence of the tactical behaviours of competitors, their related cost elements and oligopolistic market price mechanism. In chapter 4, the methodology is applied to a hypothetical Far East- North Europe liner service loop case study. In chapter 5, results of the case study are analysed and discussed. In chapter 6, conclusion of the research and future research direction are given.

2. Literature Review

A wide academic literature exists regarding to competition analysis and capacity deployment problem of the liner shipping. Panayides and Cullinane (2002) addressed strategic issues of the liner shipping competition. They clarified theoretical background of competitive advantage in liner shipping industry by applying the famous management guru Michael E. Porter's ideas and resource based view. In addition, as Srivastava *et al* (2001) mentioned market based view and as Grant (1996) explained knowledge-based (technology) view should be considered as other theories could be applied to the liner container shipping in order to gain competitive advantage. Progoulaki and Theotokas (2010) investigated the resource based view in shipping competitiveness. In their research they adapted the resource based view to human source and crew management sections of a shipping company in order to gain competitive advantage. Greeve (2009) mostly focused on the impact of innovation on the shipping competitiveness and compared the diffusion of panamax container ships with double hull oil tankers. In another similar study, Poulis et al (2013) compared competitiveness of shipping companies in consideration of their information communication technologies. On the other hand, majority of the studies in the literature utilised market based view. Dimitriu *et al* (2007) utilised agent based simulation and game theory approach in order to generate a competitive short sea passenger shipping network. In terms of liner container shipping, Yong (1996) carried out a game theoretic research on the competition among three deep sea shipping liners where the shipping liners are determined as an incumbent firm, a potential entrant and a buyer. His results claimed that exclusive dealing contracts could be significant market barriers to entry when the entrant player has a limited capacity.

Some innovative ideas were also applied on the differentiation strategies of the liner container shipping. Acciaro (2011) proposed a liner container shipping service differential model based on advance booking. His model included different pricing for loyal customers and integrated logistic service provider's customer relations strategies to the shipping liners. In a recent study Linstad *et al* (2016) suggested that shipping liners could provide two different kinds of liner services in order to satisfy different customer requirements on the same liner service loop: one fast and one relatively slow service in terms of transit time. Their approach suggested that while fast service with higher price would be more competitive against air freight and fast moving goods, the slow service would be more competitive against traditional general cargo and minor bulk trade. In addition, Zang and Lam (2015) analysed impacts of high liner shipping sailing schedule with high frequency for shippers and consignees. Their numerical analysis indicated that high liner shipping frequency is very significant for the products have high value density, high inventory cost, low demand variability and high service level requirement. The study was in favour of the shipping alliance ideology based on increasing the liner shipping port call frequency on a certain liner service loop and creating differentiation.

The cost reduction is one of the main motivations behind of competitiveness researches on liner shipping industry. Main costs of a liner shipping company are voyage costs, operational costs, capital costs, and additional costs (Gkonis and Psaraftis, 2007; Stopford, 2009). Especially voyage optimisation methods are very popular approaches in order to minimise the operation cost of the liner shipping management. For instance, in a recent study, Wang et al (2015) carried out a detailed investigation on the seasonal revenue management of a shipping liner management. They developed a mixed integer linear programming profit maximisation model with a convex objective function based on a tailored branch and bound method. Their numerical applications showed that how the optimal solution changed the cost variations in bunker price, demand and freight rate.

In addition to these researches, a variety of academic research has been published on the application of the game theoretical analysis to liner shipping service transport network and the stability of strategic shipping alliances in 2000s. Song and Panayides (2002) developed a conceptual framework of application of cooperative game theory on liner shipping alliances to indicate cooperation pay offs among shipping alliance members. Abito (2005) modelled excess capacity in the liner shipping alliances with non-cooperative two player game theory. He assumed price as equal to cost per container slot in his model. He emphasised that an agreement without explicit control on the investment would cause capacity oversupply and less cost efficiency. Shi and Voss (2011) provided a survey on game theoretical approaches within the shipping industry. Agarwal and Ergun (2010) applied mathematical programming and game theory to address tactical problems such as liner container shipping network design mechanism. Panayides and Wiedmer (2011) studied three big alliances in deep sea liner container shipping and compared their operational performance to each other. Ding and Liang (2005) focused on the partner selection for shipping alliances. They used fuzzy MCDA methodology to assist the partner selection process. Kuo and Luo (2015) investigated overcapacity supply and developed a two-player game theory model to analyse the outcomes of uncoordinated optimal ship capacity investment strategies under perfect competition. Their results suggested that the ship capacity investment has higher benefits with reduction of the bunker consumption and increase of the energy efficiency.

3. Methodology

Methodological aspect of this paper addresses practical capacity deployment rationales of the shipping alliances based on the December 2015 alliance structures. It also adapts the static Cournot heterogeneous four player capacity allocation game concept to the shipping liner alliance market competition with an integrated research framework. The mathematical steps of the methodology generated includes cost calculations of the players, Cournot competition optimal capacity deployment and freight mechanism, additional capacity increase or capacity reduction decision scenarios, Nash pure solutions for the complete information state of the players. By this methodological application, it is aimed to determine the equilibrium points of the market for different decision making alternatives. The methodological steps of the paper could be simplified as in the following figure.

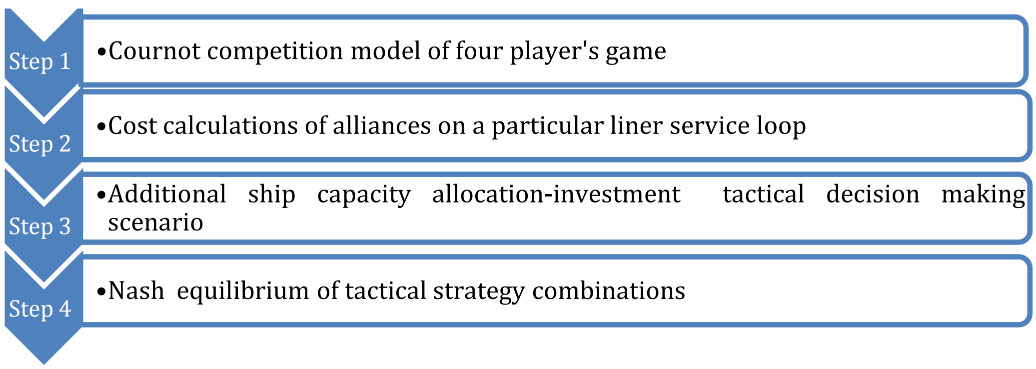

Figure 1 – Methodology of the study

The Cournot competition model is commonly applied for the case of oligopolistic control of a group of firms on the freight determination in a particular market. This study assumes the deep sea liner container shipping market as a four player oligopoly consisting of the existing shipping alliances which can be called "alliance quadropoly". The study disregards cooperation at any level between alliances and individual alliance members and assumes a perfect competition among alliances where a complete information flow is provided.

In the case of four non-cooperative fully competing players, let $q_\theta(t), \theta = 1,2,3,4$ indicates the ship capacity deployments of the quadropolistic competition counterparties during a certain t time period in the market boundaries. It is assumed that the freight of the liner shipping services P has a direct mathematical relationship with total deployed shipping capacity $Q = \sum_{\theta=1}^{4} q_\theta$ through inverse demand function $P = f^{-1}(Q)$ of economy theory which is a linear function assisting to simplify and explain the capacity-freight relationship. The average shipment price (ocean freight) of the liner service on a specific loop that quadropoly supply can be shown as $P = a - b_1q_1 - b_2q_2 - b_3q_3 - b_4q_4$ where a is a constant parameter that representing the market behaviour, and b_1, b_2, b_3, b_4 are the constant slopes of the market from each player's market position. In order to calculate the profit functions of the players, let the average container port-to-port shipment round trip cost function of the players be $C_\theta(q_\theta) = c_\theta q_\theta,\ \theta = 1,2,3,4$ and revenue of the players be $q_\theta,\ \theta = 1,2,3,4$. Therefore, the profit function of player 1 is $\pi_1 = Pq_1 - c_1q_1$, the profit function of player 2 is $\pi_2 = Pq_2 - c_2q_2$, the profit function of player 3 is $\pi_3 = Pq_3 - c_3q_3$, and the profit function of the player 4 is $\pi_4 = Pq_4 - c_4q_4$. Then it is possible to formulate the profit functions of the each player as below.

$$\pi_1 = (a - b_1q_1 - b_2q_2 - b_3q_3 - b_4q_4 - c_1)q_1$$

$$\pi_2 = (a - b_1q_1 - b_2q_2 - b_3q_3 - b_4q_4 - c_2)q_2$$

$$\pi_3 = (a - b_1q_1 - b_2q_2 - b_3q_3 - b_4q_4 - c_3)q_3$$

$$\pi_4 = (a - b_1q_1 - b_2q_2 - b_3q_3 - b_4q_4 - c_4)q_4$$

According to Cournot oligopoly model marginal profit functions or each player can be found as following (Elsadany, 2013).

$$\emptyset_\theta(q_\theta, Q_{-\theta})\frac{\partial \pi_\theta(q_\theta, Q_{-\theta})}{\partial q_\theta} = a - 2b_\theta q_\theta - b_{-\theta}Q_{-\theta} - c_\theta = 0$$

Where;

$$Q_{-\theta} = \sum\nolimits_{\mu=1,\theta\neq\mu}^{4} q_\mu$$

Using the above model it is possible to show marginal profit of each counterparties of the quadropolistic game as follows.

$$\frac{\partial \pi_1(q_1, Q_{-1})}{\partial q_1} = a - 2b_1q_1 - b_2q_2 - b_3q_3 - b_4q_4 - c_1 = 0$$

$$\frac{\partial \pi_2(q_2, Q_{-2})}{\partial q_2} = a - 2b_2q_2 - b_1q_1 - b_3q_3 - b_4q_4 - c_2 = 0$$

$$\frac{\partial \pi_3(q_3, Q_{-3})}{\partial q_3} = a - 2b_3q_3 - b_1q_1 - b_2q_2 - b_4q_4 - c_3 = 0$$

$$\frac{\partial \pi_4(q_4, Q_{-4})}{\partial q_4} = a - 2b_4q_4 - b_1q_1 - b_2q_2 - b_3q_3 - c_4 = 0$$

Then the best response capacity allocations of each player can be written in the form of Cournot oligopoly model.

$$q_1{}^* = \frac{a - b_2q_2 - b_3q_3 - b_4q_4 - c_1}{2b_1}$$

$$q_2{}^* = \frac{a - b_1q_1 - b_3q_3 - b_4q_4 - c_2}{2b_2}$$

$$q_3{}^* = \frac{a - b_1q_1 - b_2q_2 - b_4q_4 - c_3}{2b_3}$$

$$q_4{}^* = \frac{a - b_1q_1 - b_2q_2 - b_3q_3 - c_4}{2b_4}$$

In order to show mathematical relationship between optimal capacity deployment of the players and the fixed shipping price of four player oligopoly by Cournot model, the following equations are generated.

$$q_1{}^* = \frac{P - b_1q_1{}^* - c_1}{2b_1}$$

$$q_2{}^* = \frac{P - b_2q_2{}^* - c_2}{2b_2}$$

$$q_3{}^* = \frac{P - b_3q_3{}^* - c_3}{2b_3}$$

$$q_4{}^* = \frac{P - b_4q_4{}^* - c_4}{2b_4}$$

In final form of the equations, we can simply show the capacity allocations of the players as:

$$q_1{}^* = \frac{P - c_1}{3b_1}$$

$$q_2{}^* = \frac{P - c_2}{3b_2}$$

$$q_3{}^* = \frac{P - c_3}{3b_3}$$

$$q_4{}^* = \frac{P - c_4}{3b_4}$$

In the existence of the allocated capacities, the above equations will assist us to find the b_θ slopes of the market ($\theta = 1{,}2{,}3{,}4$) for each players and to determine a values of the market where fixed price per unit is known and cost per unit of each player is calculated.

In the case of liner shipping services, in order to calculate the total cost (TC_θ) of each player ($\theta = 1{,}2{,}3{,}4$) on a specific round trip service, with identical ships, it is required to calculate voyage costs (VC_θ), operational costs (OC_θ), and capital costs (CC_θ) (Stopford, 2009).

$$TC_\theta = VC_\theta + OC_\theta + CC_\theta$$

Simply the voyage cost of each player ($\theta = 1{,}2{,}3{,}4$) may be calculated as sum of the average bunker costs (BC_θ) , average port charges(PC_θ) and any required canal charges (γ).

$$\sum_{i=1}^{n-1}\sum_{j=2}^{n} VC_{\theta_{ij}} = \sum_{i=1}^{n-1}\sum_{j=2}^{n} BC_{\theta_{ij}} + \sum_{k=1}^{n} PC_{\theta_k} + \gamma$$

The operational cost of players ($\theta = 1{,}2{,}3{,}4$) may be calculated as sum of manning cost (MC_θ), insurance cost (IC_θ), stores (SC_θ), maintenance (MAC_θ), and administration costs (ADC_θ).

$$OC_\theta = MC_\theta + IC_\theta + SC_\theta + MAC_\theta + ADC_\theta$$

In order to calculate number of round trips for a ship per year, it is required to calculate total round trip time. The total rime requires for a liner service round trip is calculated as below.

$$RT_\theta = \sum_{i=1}^{n-1}\sum_{j=2}^{n} \frac{D_{\theta_{ij}}}{V_{\theta_{ij}}} + \sum_{k=1}^{n} PT_{\theta_k} + \sigma_\theta$$

Where;

RT_θ =Round trip time (hours) of the liner service of players

$D_{\theta_{ij}}$= Route distance between i^{th} and j^{th} port of call

$V_{\theta_{ij}}$= Average speed between i^{th} and j^{th} port of call

PT_{θ_k} =Average port time of k^{th} port of call

σ_θ = Average total round trip delays from unexpected port waiting, maintenance and weather

Capital cost per ship round trip of each player (CC_θ) may be calculated with following formula for $\theta = (1,2,3,4)$.

$$CC_\theta = CP_\theta + n_\theta * \frac{r_\theta * (1 + r_\theta)^{n_\theta}}{(1 + r_\theta)^{n_\theta} - 1} * l_\theta$$

Where;

CP_θ = Cash price of the average ship of each player

r_θ = Interest rate of the average ship of the players for adequate time period

n_θ = Number of instalment for each player

l_θ= Loan of the players

Then the number of round trips per year for a ship is $y_\theta = \frac{365*24}{RT_\theta}$ with largest integer possible. If it is assumed that the liner service provides weekly service from each port of calls, it is required to allocate $x_\theta = \frac{52}{y_\theta}$ number of ships with largest integer possible. The total annual cost of a liner service loop for a shipping alliance/shipping liner is shown as below.

$$c_{\theta-Annual} = (y_\theta * x_\theta * TC_\theta) + AC_\theta \quad , \quad \theta = (1,2,3,4)$$

Where;

AC_{θ} = Annual additional costs per service loop

Based on the given total annual cost, the average per container shipment cost c_{θ} could be shown as following.

$$c_{\theta} = \frac{c_{\theta-Annual}}{y_{\theta}*x_{\theta}*q_{\theta}*\omega_{\theta}} \quad , \quad \theta = (1,2,3,4)$$

Where;

ω_{θ}= Capacity utilisation rate of the liner service of player θ

Let δ_{θ} is a particular additional capacity decision that shipping liners could employ on the liner shipping service by enlarging the average ship size. New capacity of a shipping alliance could be expressed as:

$$q"^{*}_{\theta} = q^{*}_{\theta} + \Delta\delta_{\theta}$$

Where;

$\Delta\delta_{\theta}$ is 0 or $\pm\ \delta_{\theta}$

$q"^{*}_{\theta}$ is capacity allocation of in the new scenario.

In final form of the previous equations, we can simply show the capacity allocations as:

$$q"_{\theta}{}^{*} = \frac{P" - c_{\theta}"}{3b_{\theta}}$$

Where;

$\theta = (1,2,3,4)$

$P"$ is the new freight rates based on the capacity deployment decision

$c_{\theta}"$is the new cost per container based on the capacity deployment decision.

In heterogeneous four player game let the pure strategy set of the player θ is denoted by $S^{\theta} = \{s^{\theta}_{\mu} \,|\, \mu \in M_{\theta}\}$ with $M_{\theta} = \{1, \dots m_{\theta}\}$ where it is assumed that all players have m_{θ}=2 pure strategies in order to simplify the model. The set of all pure strategy profiles is $S = \prod_{\theta=1}^{4} S^{\theta}$. The profit payoff function of player θ is denoted by $\pi^{\theta}: S \rightarrow R$.

It is possible to represent the total number of pure strategies in the quadropoly game as $\sum_{\theta=1}^{4} m_\theta$, and pure strategy combinations in the game as $\prod_{\theta=1}^{4} m_\theta$. Thus, the number of pure strategies in game is 8 and the pure strategy combinations in the game is 16. Briefly all pure strategy combinations in the game could be shown as following (Chatterjee, 2009).

$$(s_1^1, s_1^2, s_1^3, s_1^4) \coloneqq Combination\ 1 \qquad (s_2^1, s_2^2, s_2^3, s_2^4) \coloneqq Combination\ 9$$

$$(s_1^1, s_2^2, s_1^3, s_1^4) \coloneqq Combination\ 2 \qquad (s_2^1, s_1^2, s_2^3, s_2^4) \coloneqq Combination\ 10$$

$$(s_1^1, s_1^2, s_2^3, s_1^4) \coloneqq Combination\ 3 \qquad (s_2^1, s_2^2, s_1^3, s_2^4) \coloneqq Combination\ 11$$

$$(s_1^1, s_1^2, s_1^3, s_2^4) \coloneqq Combination\ 4 \qquad (s_2^1, s_2^2, s_2^3, s_1^4) \coloneqq Combination\ 12$$

$$(s_1^1, s_2^2, s_2^3, s_1^4) \coloneqq Combination\ 5 \qquad (s_2^1, s_1^2, s_1^3, s_2^4) \coloneqq Combination\ 13$$

$$(s_1^1, s_2^2, s_1^3, s_2^4) \coloneqq Combination\ 6 \qquad (s_2^1, s_1^2, s_2^3, s_1^4) \coloneqq Combination\ 14$$

$$(s_1^1, s_1^2, s_2^3, s_2^4) \coloneqq Combination\ 7 \qquad (s_2^1, s_2^2, s_1^3, s_1^4) \coloneqq Combination\ 15$$

$$(s_1^1, s_2^2, s_2^3, s_2^4) \coloneqq Combination\ 8 \qquad (s_2^1, s_1^2, s_1^3, s_1^4) \coloneqq Combination\ 16$$

Where;

s_μ^θ means τ^{th} pure strategy of θ^{th} player and each player has 2 available strategies in a four player game for $\theta = (1,2,3,4)$ and $\mu = (1,2)$.

With the given strategy combinations the utility profit payoff (π) combination matrix of the players in quadropoly is identified as below.

$$\begin{array}{cccc}
\pi_1^1 & \pi_1^2 & \pi_1^3 & \pi_1^4 \\
\pi_2^1 & \pi_2^2 & \pi_2^3 & \pi_2^4 \\
\pi_3^1 & \pi_3^2 & \pi_3^3 & \pi_3^4 \\
\vdots & \vdots & \vdots & \vdots \\
\pi_{15}^1 & \pi_{15}^2 & \pi_{15}^3 & \pi_{15}^4 \\
\pi_{16}^1 & \pi_{16}^2 & \pi_{16}^1 & \pi_{16}^4
\end{array}$$

Where;

π_τ^θ means τ^{th} utility profit payoff of θ^{th} player in a four player's game with two strategy choices for $\theta = (1,2,3,4)$ and $\tau = (1,2,3,4,5,6, \dots, 16)$.

F, the solution concept**,** is formulated as $F: \{s_1^\theta, \dots s_\mu^\theta, ,\pi_1^\theta, \dots, \pi_\tau^\theta\} \rightarrow s_\mu^{\theta^*}$. The strategy combination $s_\mu^{\theta^*}$ is the Nash equilibrium if no player has incentive to deviate from his strategy given that the other players do not deviate from their strategies (Nash, 1950).

Formally Nash equilibrium best response function of the game can be shown as follows:

$$\forall \theta, \forall \mu, \forall \tau \quad \pi_\tau^\theta \left(s_\mu^{\theta^*}, s_{-\mu}^{\theta}{}^*\right) \geq \pi_\tau^\theta \left(s_\mu^{\theta'}, s_{-\mu}^{\theta}{}^*\right), \forall s_\mu^\theta$$

Where;

$s_{-\mu}^{\theta}{}^*$ is the Nash equilibrium best response strategies of the other players

$s_\mu^{\theta'}$ is any alternative strategy of player θ

4. Case Study

In this section, the previously developed methodology is applied to a hypothetical Far East-Northern Europe liner service loop. The Far East-Northern Europe liner shipping market is selected due to its more balanced market share among the liner shipping alliances. The market supply shares of the alliances comparisons according to main route areas are given in the figure 2.

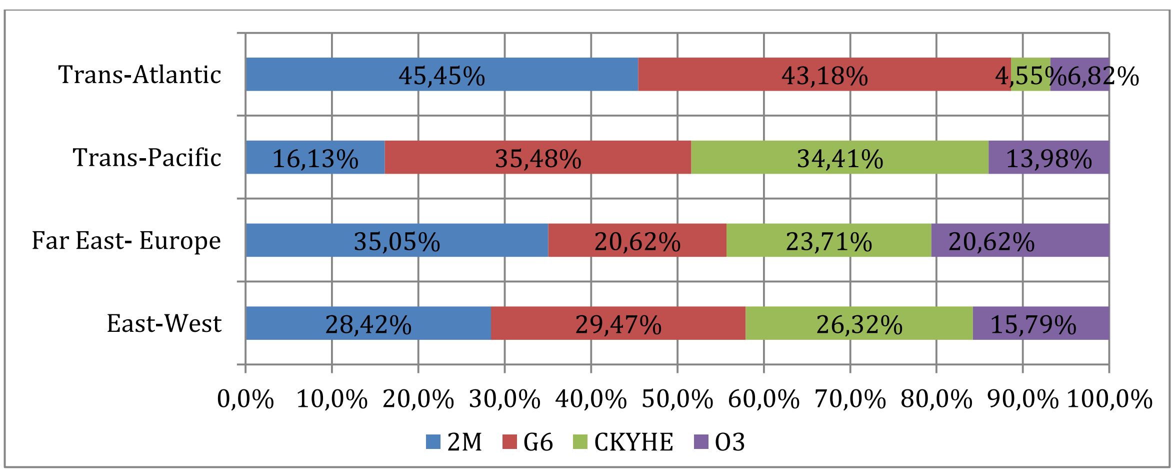

Figure-2 Market shares of the liner shipping alliance supply capacities

Source: Own eloborations based on (Alphaliner, 2015) data

This study assumes the liner shipping service of the Global alliances as identical with routes and port of calls and each alliance utilises a certain average ship sizes on the given liner shipping service route. The route consists of, including East bound and West bound, 13 voyages between 14 port of calls namely; Qingdao, Kwangyang, Busan, Shanghai, Yantian, Singapore, Algericas, Hamburg, Rotterdam, Le Havre, Algericas, Singapore, Yantian, Qingdao. Due to the Qingdao port called second time at the end of the round trip it is excluded from port of calls and the total port of calls for one round trip is accepted as 13. The visual illustration of the identically assumed Far East- Northern Europe liner service loop is illustrated as following.

Figure 3 – Typical Far East-Northern Europe liner container shipping service

For the given service loop, the current average freight rate is identified as \$650/TEU from 2015 Shanghai-Rotterdam and Rotterdam- Shanghai rates of the world container index data. Thus, the market slope values of the alliances are determined as $b_{2M} = 0.003248, b_{G6} = 0.003612, b_{CKYHE} = 0.002269, b_{O3} = 0.004404,$ and the a value is given as 900. It is assumed that the round trip time of the service loops are the same for all shipping alliances and considered as 30 days for the West Bound and 40 days for the East Bound. The bunker prices are considered as constant annually and \$200 per tonne. It is assumed that all shipping services have annual 15 days (2 weeks) delays. The port charges are accepted as \$15,000 for all port of calls and all ship sizes. In addition, the voyage costs, the capital cost and the operational costs are calculated based on the deployed ship sizes. The annual additional costs of the players are considered approximately same and as \$500,000 ship/year. The present market characteristic of the given liner container shipping service is shown in the Table. 2 including average ship sizes, weekly demands, and capacity utilisation rates, and average profits per TEU.

Table.2 Properties of the liner shipping alliances for the service route

Properties	2M	G6	CKYHE	O3
Av. Ship Size 2015(TEU)	14,000	12,300	10,800	13,400
Weekly Demand (TEU)	11,167	10,400	8,667	11,750
Market Share of Demand	26%	25%	21%	28%
Capacity Utilisation Rate	79.76%	84.55%	80.24%	87.68%
Number of Port of Calls	13	13	13	13
Round Trip (Days)	70	70	70	70
Number of Ships	10	10	10	10
Annual Round Trip per Ship	5	5	5	5
Average Profit per TEU ($)	136	133	74	177

Source: (Drewry, 2016)

6. Scenario Building

In order to analyse the competition state of the market 2 years after from present, a market scenario is generated. In this scenario, the bunker prices will climb up to $250 per tonne. It is assumed that demand for each service will increase 3.4% annually. The round trip days, number of ships on the service, annual round trip per ship, number of port of calls, port charges, and annual additional costs are assumed as same as the present. It is proposed that CKYHE is the first rational player who needs to take a rational action regarding to capacity deployment decision-making due to its lower profit. Then the G6 is the second rational player and the 2M and O3 are adaptive players. It is assumed that the competition game is static and the players determine their best strategies by consideration of the tactical strategy behaviours of the competitor shipping alliances.

According to the given scenario each player has 2 available strategy options given below:

1- No average ship capacity increase on the current average ship capacity

2- 2000 TEU capacity increase on the existing average ship capacity

Therefore, the pure strategy combinations of the alliances for capacity deployment decision making are given as following:

$$(s_{No\ Increase}^{CKYHE}, s_{No\ Increase}^{G6}, s_{No\ Increase}^{2M}, s_{No\ Increase}^{O3}) \coloneqq Combination\ 1$$

$$(s_{No\ Increase}^{CKYHE}, s_{+2000\ TEU}^{G6}, s_{No\ Increase}^{2M}, s_{No\ Increase}^{O3}) \coloneqq Combination\ 2$$

$$(s^{CKYHE}_{No\ Increase}, s^{G6}_{No\ Increase}, s^{2M}_{+2000\ TEU}, s^{O3}_{No\ Increase}) \coloneqq Combination\ 3$$

$$(s^{CKYHE}_{No\ Increase}, s^{G6}_{No\ Increase}, s^{2M}_{No\ Increase}, s^{O3}_{+2000\ TEU}) \coloneqq Combination\ 4$$

$$(s^{CKYHE}_{No\ Increase}, s^{G6}_{+2000\ TEU}, s^{2M}_{+2000\ TEU}, s^{O3}_{No\ Increase}) \coloneqq Combination\ 5$$

$$(s^{CKYHE}_{No\ Increase}, s^{G6}_{+2000\ TEU}, s^{2M}_{No\ Increase}, s^{O3}_{+2000\ TEU}) \coloneqq Combination\ 6$$

$$(s^{CKYHE}_{No\ Increase}, s^{G6}_{No\ Increase}, s^{2M}_{+2000\ TEU}, s^{O3}_{+2000\ TEU}) \coloneqq Combination\ 7$$

$$(s^{CKYHE}_{No\ Increase}, s^{G6}_{+2000\ TEU}, s^{2M}_{+2000\ TEU}, s^{O3}_{+2000\ TEU}) \coloneqq Combination\ 8$$

$$(s^{CKYHE}_{+2000\ TEU}, s^{G6}_{+2000\ TEU}, s^{2M}_{+2000\ TEU}, s^{O3}_{+2000\ TEU}) \coloneqq Combination\ 9$$

$$(s^{CKYHE}_{+2000\ TEU}, s^{G6}_{No\ Increase}, s^{2M}_{+2000\ TEU}, s^{O3}_{+2000\ TEU}) \coloneqq Combination\ 10$$

$$(s^{CKYHE}_{+2000\ TEU}, s^{G6}_{+2000\ TEU}, s^{2M}_{No\ Increase}, s^{O3}_{+2000\ TEU}) \coloneqq Combination\ 11$$

$$(s^{CKYHE}_{+2000\ TEU}, s^{G6}_{+2000\ TEU}, s^{2M}_{+2000\ TEU}, s^{O3}_{No\ Increase}) \coloneqq Combination\ 12$$

$$(s^{CKYHE}_{+2000\ TEU}, s^{G6}_{No\ Increase}, s^{2M}_{No\ Increase}, s^{O3}_{+2000\ TEU}) \coloneqq Combination\ 13$$

$$(s^{CKYHE}_{+2000\ TEU}, s^{G6}_{No\ Increase}, s^{2M}_{+2000\ TEU}, s^{O3}_{No\ Increase}) \coloneqq Combination\ 14$$

$$(s^{CKYHE}_{+2000\ TEU}, s^{G6}_{+2000\ TEU}, s^{2M}_{No\ Increase}, s^{O3}_{No\ Increase}) \coloneqq Combination\ 15$$

$$(s^{CKYHE}_{+2000\ TEU}, s^{G6}_{No\ Increase}, s^{2M}_{No\ Increase}, s^{O3}_{No\ Increase}) \coloneqq Combination\ 16$$

The Cournot-Nash complete information quadropoly game model is generated on available commercial software called GamePlan 3.7 and illustrated in figure 4. The game model of the given case study scenario includes following elements:

- The name and order of the players, and their strategy options
- The decision node connections of the players
- The pay offs of the player for each strategy combinations

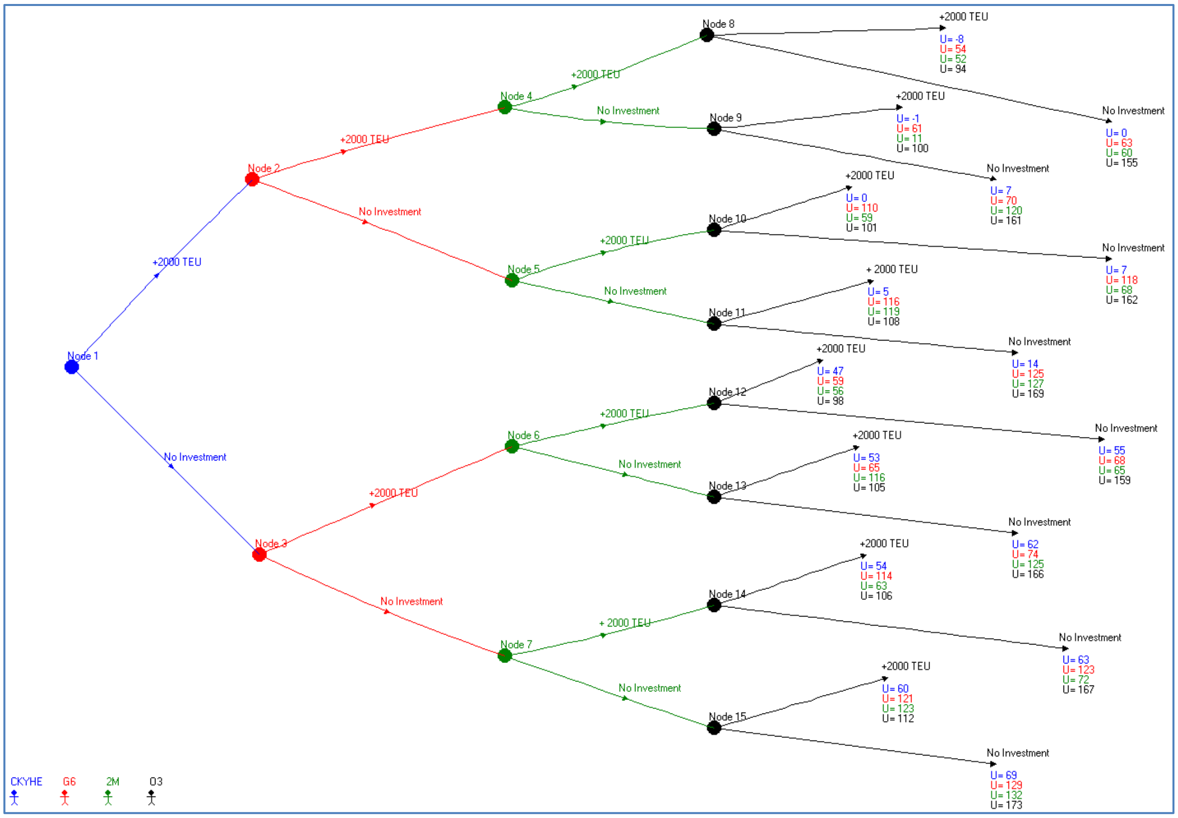

Figure 4 – Game model of the case study

7. Results

The quadropolistic analysis of the capacity provides many results regarding to tactical competition strategy outcomes. These results includes market freight rates, costs of TEU transported for all players, profit distribution of the players according to selected strategy combinations, Nash equilibrium point of the strategy combinations. In addition, the results of the model provide annual cost elements, revenue, and profit comparisons of the competitor shipping alliances at the equilibrium point. Therefore by applying this model it is possible to reach financial outcome of the chosen competitive investment strategies. In figure 5, the changes of the freight rates of the market according to chosen strategy combinations are given. It is also possible to understand revenue changes of the players from the freight rates. Based on the given freight rates, it is understood that capacity increase investment in the current market situation further reduces the market freight rates and revenues of the liner container shipping alliances. While the strategy combination 1 is providing the highest freight rates, the strategy combination 9 provides the lowest freight rates and revenue.

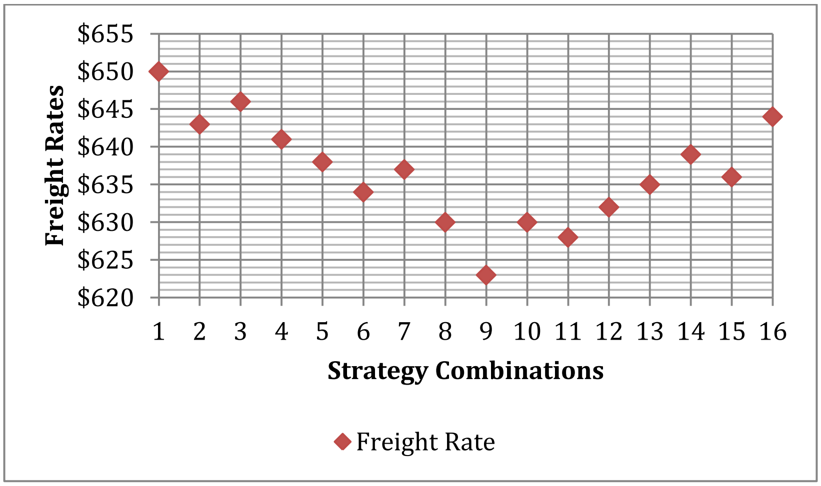

Figure 5 – Freight rates according to strategy combinations

The methodology applied in this study provides changes of the costs per TEU transported of the alliances for each strategy combination. The cost per TEU changes of the alliances based on the strategy combinations are given in figure 6. According to determined cost behaviours, the CKYHE shipping alliance has competitive cost disadvantage against other shipping alliances for all strategy combinations. On the other hand, for all players, whilst the capacity increase decision increases the costs, the no capacity increase investment decision reduces the costs.

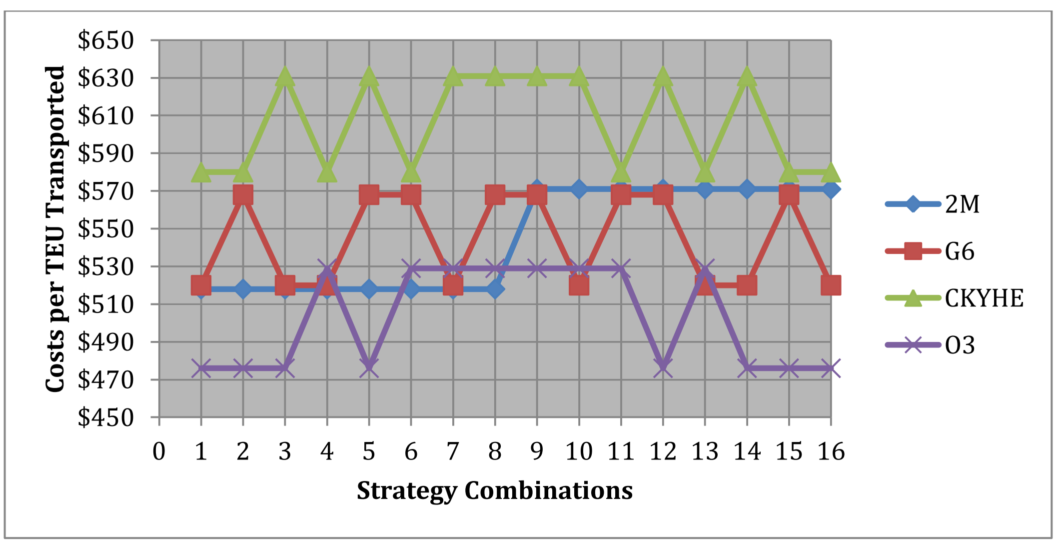

Figure 6 –Costs per TEU transported according to strategy combinations

The figure 7 illustrates the profit distribution of the shipping alliances in a 3D form according to each given strategy combinations. From the given figure it is possible to see the deep and peak points of the profit distributions for each shipping alliance.

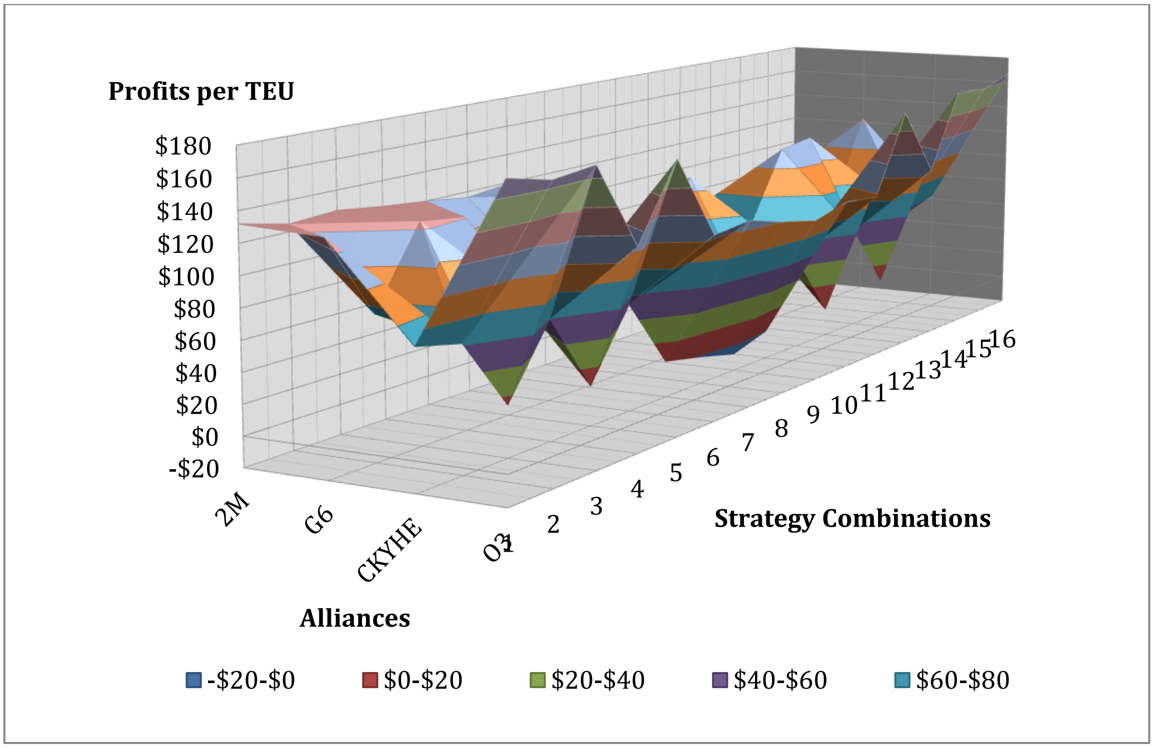

Figure 7 – Profit distribution according to strategies of the alliances

The figure 8 provides the Nash equilibrium solution results of the game. The strategy combination 1 is determined as the equilibrium point of the game which is illustrated with a complete straight line from the node of the player 1 to player 4. Also, the results on the GamePlan 3.7 software provides some detailed numerical outcomes of the tactical strategy selection of the alliances. The “p” symbols shown in the figure 8 are the probabilities of each move at each game node. As a consequence of the utilisation of the Cournot-Nash pure strategy solution is utilised, p values found as only equal to 0 and 1. Another given symbol “e” is the expected pay offs of the strategy choices between decision nodes. “E” represents the expected pay offs of each player at each node. “U” shows the zero sum utilities (pay offs) of each final strategy moves.

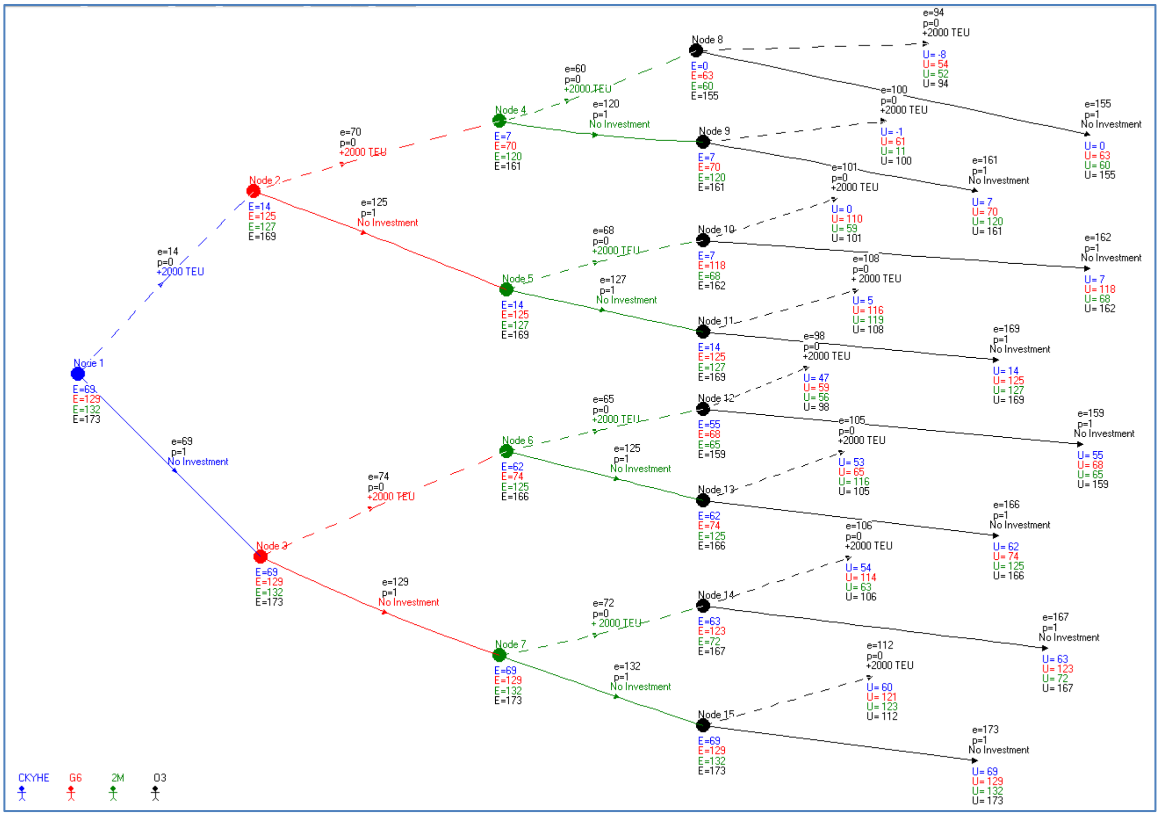

Figure 8 – Nash Equilibrium solution of the alliance quadropoly game

After determination of the equilibrium point of the game, the financial situations of the alliances are comparatively shown in figure 9. According to results the O3 alliance is determined as the most competitive shipping alliance.

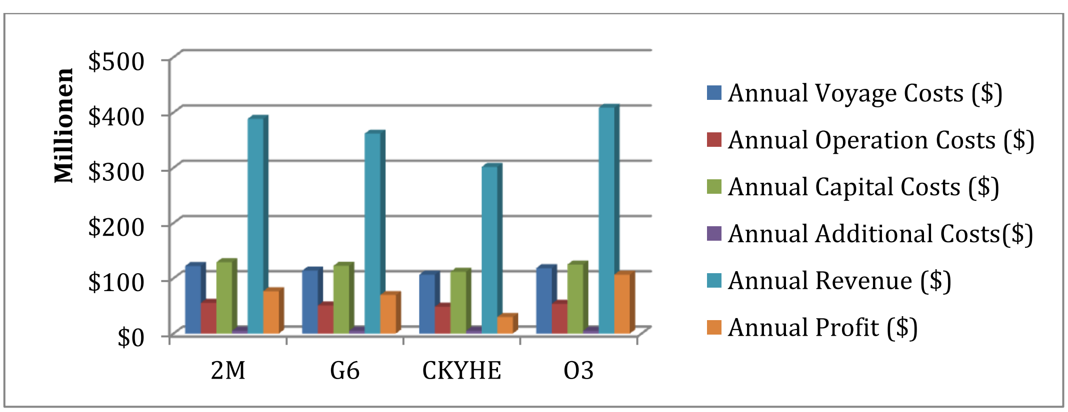

Figure 9 – Annual costs, revenue and profit of the alliances in equilibrium point

8. Conclusion

This study addresses the development a game theoretical analysis tool for the liner container shipping alliance competition on a particular liner service loop. The study integrates shipping economics practices with capacity deployment related tactical decision making concepts. In this study, it is clearly emphasised that the capacity deployment decision making on a specific liner service loop should include the competitive behaviour of competitors. According to the obtained results, O3 shipping alliance is determined as the most competitive shipping alliance and CKYHE shipping alliance is found as the least competitive shipping alliance. Recent merge of the Cosco- CSCL and Cosco's decision to be a part of O3 shipping alliance is supporting the results of this study.

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