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The Effects of Slow Steaming on the Liners' Operating Strategy

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Abstract : *In recent times, an obvious strategy in liner shipping markets that has come to the fore is slow steaming. Nowadays, most liner shipping companies have decelerated the voyage speed to 15-18 knots on major routes, and some leading liner shipping companies have a plan to reduce it to below 15 knots. Slow steaming is helpful in reducing the operating cost and the amount of greenhouse-gas emissions on a single vessel with lower fuel consumption. However, it also creates various negative effects such as the opportunity cost, additional fixed costs and an in-transit inventory cost on a loop. Hence, the net operating cost on a loop is changing dynamically due to the changes of voyage speed based on various slow steaming effects. The aim of this study is to analyze the slow steaming effects in the liner shipping, and to find the best voyage speed that minimizes the operating cost on a loop. Moreover, this study suggests the recommendable strategy for liner shipping companies. To achieve the aim of this study, a simulation model has been designed using System Dynamics.*

Key words : *liner shipping company, slow steaming, the best voyage speed, operating costs, system dynamics*

1. Introduction

1.1 Background

Liner shipping companies have always pursued the optimal solution to achieve the twin goals of the expansion of transport capability and the reduction of operating costs not only to secure competitiveness but also to survive in competitive markets of unanticipated change. This is because the liner shipping industry is sensitive to the changes of the economic and market conditions. Therefore, the excessive investment strategy can lead to financial difficulties, while the conservative investment strategy can impede efficient and/or timely investment.

Moreover, the liner shipping industry is capital intensive and requires high fixed costs (Stopford, 2007; Notteboom, 2006), so a trade-off between both goals is one a serious issue for liners. For this reason, during the last three decades liners have been using various strategies to achieve their goals of minimizing the input of assets and maximizing operational efficiency. For example, they have been focusing on the increase of employed vessel size to enjoy the economies of scale. Moreover, they have been improving their transport networks through introducing the Hub & Spoke, market segmentation and service diversification, and strengthening the cooperation with competitors through strategic alliance, slot chart and joint service to improve their operational efficiency and to reduce their operating costs.

In particular, during the 10 years before 2009, the liner shipping industry experienced the serious shortage of transport capacity as a result of the faster growth in transport demand than expected. Therefore, liners focused on the expansion of their transport capability through new construction order and/or Merger and Acquisition (M&A). Moreover, liner shipping companies have improved their operational efficiency by the acceleration of the voyage speed. For instance, in the case of the westbound service on the Far East-North Europe route, liners have reduced the number of vessels and the number of calling ports on each loop, while they have increased the average vessel size actively as shown in Table 1. In this sense, the main operational strategy of liners in this period can be defined as the maximization of the transport capability to the

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maximum level by the acceleration of voyage speed using the large container ship on major routes.

However, nowadays, one of the obvious strategies in the liner shipping markets is slow steaming. An average voyage speed on major routes has been decelerated to 18-20 in 2010, and 15-18 knots in 2011, and some leading liners have a plan to reduce it to below 15 knots (McCarthy, 2012). This is because, in the market condition of higher bunker fuel prices and low freight rates, slow steaming is helpful in reducing the operating costs (Notteboom and Vernimmen, 2008; Ben, 2009) and the amount of GHG emissions (Ronen, 2011; Cariou and Cheaitou, 2012; IMO, 2009) by the reduction of bunker fuel consumption. According to Maersk-Line, when voyage speed is decelerated by 20%, the bunker fuel consumption and the amount of CO_2 emissions can be reduced by more than 40% and 20% respectively.

1.2 Aim of Study

This study started with some basic questions. Firstly, is it true that the more voyage speed is reduced the more operating cost and the amount of GHG emissions can be reduced at the same time? Secondly, what is the best speed to minimize the operating cost and slot cost? If the first question is true, liners will reduce their voyage speed as much as they can. Otherwise, liners need to find the best voyage speed to minimize their operating cost and to strengthen their price competitiveness. Thirdly, what does slow steaming have to do with the vessel size? If there is a strong correlation between slow steaming and vessel size, as liners decelerate the voyage speed and as they increase the vessel size, they can enjoy both benefits of the effects of slow steaming and the economies of vessel size at the same time. If not, liners need to choose either one of two strategies.

Regarding the optimization of the operating cost and fleet organization, Jansson and Shneerson (1982) constructed an economic model to analyze the liner shipping service to minimize the total operating and inventory costs, and Perakis and Jaramillo (1991) designed a liner programing model for a routing strategy to minimize the operating cost over a planning time horizon. Moreover, Fagerholt (1999), Mourao et al. (2002) and Bendall and Stent (2001) developed a model to decide the optimal liner routing, vessel size and sailing frequency to minimize the operating cost and inventory cost. Moreover, regarding the GHG emissions, numerous studies focus on the estimation of the amount of GHG emissions occurring by ship. Recently, the amount of air pollutions from the ship was estimated by IMO (2009) and Apollonia et al. (2010). The relationship between fuel prices and the operating costs was analyzed by Cariou and Notteboom (2011) and Eide et al. (2011) estimated the cost for the reduction of GHG emissions using scenarios in the shipping industry. Kim et al. (2009) analyzed the relationship between the operating cost and the CO_2 emissions in intermodal transport networks.

Regarding the relationship between slow steaming and the operating costs in liner shipping, various studies have verified the effectiveness of slow steaming. Notteboom and Vernimmen (2008) built a cost decision model to analyze the impact on the operating cost by the changes of bunker fuel price, and Ronen (2011) analyzed the relationship between the oil prices, vessel size and voyage speed in the liner shipping markets. Moreover, Cariou and Cheaitou (2012), Woo and Moon (2013) argued the sustainability of slow steaming from the economic and environmental viewpoints. Nevertheless, there remains an unexplained aspect to solve above basic questions. In this sense, this study sets three objectives of study. The first objective is to analyze the relationship between voyage speed and the operating cost on a loop. The second is to find the best voyage speed to minimize the operating cost on a loop, and the third is to build the optimum operating strategy for liner shipping companies.

2. Concept and Definition

2.1 The relationship between Voyage speed and operating costs

As discussed above, slow steaming is helpful to reduce the operating costs and the external cost by the reduction of bunker fuel consumption and the amount of GHG emissions (Positive Effect 1 and 2). However, it also creates additional costs on a loop. The first cost to consider is an opportunity cost (Negative effect 2). This occurs by giving up the transport capability through the deceleration of voyage speed. Hence, as the voyage speed decreases, an opportunity cost would be increased. Moreover, as the voyage speed is decelerated, the fixed costs and variable costs, except fuel cost, are also increased (Negative effect 1). This is because slow steaming requires the increase of the number of vessels on a loop to keep its weekly service schedule. In addition to this, slow steaming leads to an

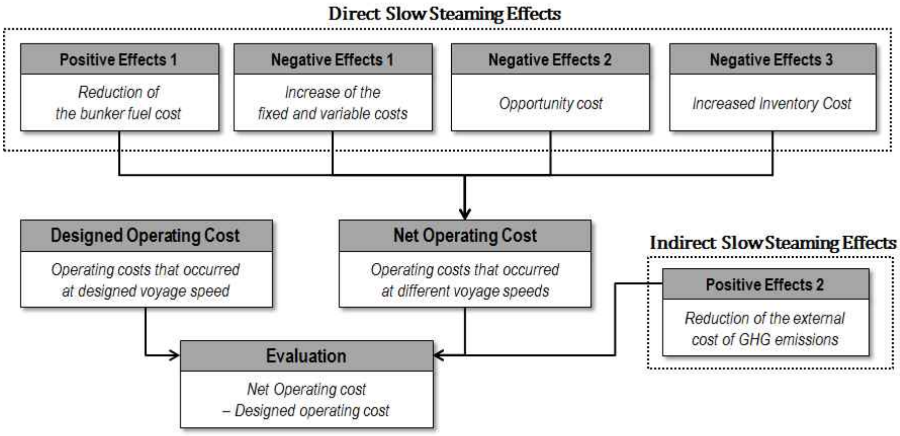


Fig. 1 Impact of slow steaming in liner shipping

increase an in-transit inventory cost by the increase of transit time on a loop (Negative effect 3). In this sense, this study defined these effects as the slow steaming effects in liner shipping, and classified it into two categories of the direct slow steaming effects and the indirect slow steaming effects as shown in Figure 1. This study focused on the direct slow steaming effects to analyze net effects of slow steaming on the operating costs on a loop.

2.2 Definition of slow steaming effects

The changes of the amount of fixed costs and variable costs on a loop (ADOP; Negative effect 1) can be derived by multiplying the changed number of employed vessel on a loop (INV) by the annual designed operating cost on a single vessel (DOCv); ADOP=INV DOCv. Moreover, an opportunity cost on a loop (OPrta; Negative Effect 2) can be derived by multiplying an opportunity cost on a single vessel (OPrtv) by the required number of vessels on a loop (Nvs). In this formula, an opportunity cost on a single vessel (OPrtv) can be defined as multiplying the changed annual operating time (day) by the daily designed operating cost on a single vessel (DOCd), and this relationship can be expressed by formula (1).

The required number of employed vessels on a loop (Nvs) can be derived by formula (2) and (3). In this formula, the number of employed vessels on a loop is decided by the turnover ratio (TOR), and the turnover ratio is influenced by the voyage distance, vessel size, number of call ports and voyage speed directly. Moreover, the changes of the in-transit inventory cost (IAIC: Negative Effect 3) can be defined as a difference between an in-transit inventory cost at a designed voyage speed (AICd) and an in-transit inventory cost at different voyage speeds (AICs), and it can be derived by formula (4).

$$OPrta = OPvtv \cdot Nvs = [(DRTd - RTd) \cdot (Nd - Ns) \cdot DOCd] \cdot Nvs \quad \text{– (1)}$$

where;

OPrtv: annual opportunity cost on a single vessel (US$)

OPrta: annual opportunity cost on a loop (US$)

DRTd: designed round-trip time at 25 knots (day)

RTd: changed round-trip time at different voyage speeds (day)

DOCd: daily operating costs/Vessel (US$)

Nd: annual turnover ratio at 25 knots (times)

Ns: annual turnover ratio at different voyage speeds (times)

Nvs: required number of vessel on a loop

$$Nvs = 52/TOR = 52/[(365 \cdot 24)/RT] \quad \text{--- (2)}$$

$$RT = 2 \cdot [(VD/CVS) + (2 \cdot AVS)/ABP] + TPT \quad \text{--- (3)}$$

where;

Nvs: required number of employed vessels on a loop

TOR: turnover ratio (times)

RT: roundtrip-time (Hr)

CVS: actual voyage speed (knots)

VD: voyage distance (mile)

AVS: average vessel size (TEU)

ABP: average berth productivity (TEU/Hr)

TPT: total port time (Hr)

$$IAIC = AICd - AICs = [Q \cdot (Td - Ts)/365 \cdot (D/Q) \cdot Vg \cdot Iit] \quad \text{-- (4)}$$

where;

IAIC: annual in-transit inventory cost (US$)

AICd: annual in-transit inventory cost at designed voyage speed (US$)
AICs: annual in-transit inventory cost at different voyage speeds (US$)
Q: units in in-transit inventory each shipment
D: annual transport volume (TEU)
Td: transit time at designed voyage speed (day)
Ts: transit time at different voyage speeds (day)
Vg: average value of goods per TEU (US$)
Iit: percentage of investment in in-transit inventory) (percentage)

On the other hand, as discussed above, slow steaming has influence on the annual fuel cost directly. The amount of annual saving fuel consumption on a loop (ASFCl) can be derived by multiplying the amount of annual saved fuel consumption on a single vessel (ASFCv) by the number of vessels on a loop (Nvr). In this formula, the amount of annual saving fuel consumption on a single vessel (ASFCv) can be defined as the difference between the amount of annual fuel consumption at the designed voyage speed and the amount on a single vessel at different voyage speeds as shown in formula (5). Moreover, this study defined the designed operating cost (DEOC) as the operating cost that occurs at the designed voyage speed, and it can be derived by multiplying the number of employed vessels on a loop (Nvs) by the annual designed operating cost on a single vessel (DEOCV); DEOC= Nvs • DEOCv. In this model, both indicators are fixed by assumption of simulation model, so the designed operating cost is fixed. Moreover, based on the above definitions, net operating cost can be defined as the following formula (6).

$$ASFCl = \begin{bmatrix} \left((SFOCv \cdot EP \cdot Od) \cdot \frac{24}{10^6} \right) \\ - \left(\left(SFOCv \cdot EP \cdot \left(\frac{AVS}{DVS} \right)^3 \cdot Od \right) \cdot \frac{24}{10^6} \right) \end{bmatrix} \cdot Nvs - \quad (5)$$

where;
ASFCl: the amount of annual saving fuel consumption/loop (US$)
SFOCv: specific fuel oil consumption at different voyage speeds (ton/knots)
EP: engine power (Kw)
AVS: changed voyage speed (knots)
DVS: designed voyage speed (knots)
Od: annual operating time at sea (day)

$$\begin{aligned} NOC &= DEOC + (PSSE - NSSE) \quad ---- \ (6) \\ &= DEOC + (Csa + OPrta + ADOP + IAIC) \end{aligned}$$

where;
NOC: net operating cost/loop (US$)
DEOC: designed operating cost/loop (US$)
PSSE: positive slow steaming effects (US$)
NSSE: negative slow steaming effects (US$)

2.3 Evaluation of net slow steaming effects

Net slow steaming effects can be verified by the comparison between the net operating cost and the designed operating cost. When the net operating cost (NOC) is lower than the designed operating cost (DEOC) at a specific voyage speed, i.e. NOC-DEOC≤ 0, the positive effects is larger than the sum of the negative effects. It means that liners can reduce their annual operating cost on a loop using slow steaming, or if both costs are equal to each other, they can maintain their operating cost as much as the annual designed operating cost. However, in the reverse situation, i.e. NOC - DEOC > 0, liners can suffer a loss by slow steaming.

In this sense, this study defined the optimal operating cost, the best voyage speed and the economic range of voyage speed as follows. Firstly, the optimal operating cost of a loop is the lowest value of the net operating cost (NOC) on the conditions of NOC - DEOC≤ 0. Moreover, in this situation, the specific voyage speed to minimize the net operating cost (NOC) is defined as the optimal voyage speed. Furthermore, the economic range of voyage speed can be defined as the specific range of voyage speed that fulfills the condition of NOC - DEOC ≤ 0. Hence, when liners control their voyage speed to the optimal voyage speed, they can minimize their operating cost on a loop. Moreover, when they control their voyage speed within the economic range of voyage speed, they can reduce or maintain their operating cost in comparison with the designed operating cost. On the contrary, when the net operating cost (NOC) is higher than the designed operating cost (DEOC), *i.e.* NOC - DEOC > 0, slow steaming has a negative influence on the operating costs on a loop. In this case, the optimal operating cost and the best voyage speed are decided at the designed voyage speed. In other words, when the net operating cost (NOC) is higher than the designed operating cost (DEOC), liners have to decide to abandon slow steaming and control their voyage speed to the designed voyage speed.

Table 1 Comparison of containership characteristics for vessel range

Containership Size Class		6,000	8,000	10,000	12,000	14,000
LOA (m)		304	323	363.8	393.3	407.9
Design Deadweight (ton)		61,700	82,200	114,900	140,600	165,800
Design Draft (m)		12	13	15.4	15.7	16.2
Designed voyage Speed (knots)		25	25	25	25	25
Main Engine (Output) (MCR Kw)		57,100	68,500	74,000	82,100	89,700
Total Installed Aux. (Kw)		12,900	12,000	12,000	14,000	16,000
Fuel Consumption	at sea	246	286	307	342	375
(ton/day)	in port	26	24	24	28	32
Daily Operating Cost (000 US$)		13.8	18.48	23.1	27.7	32.3

Source: MAN Diesel & Turbo(2012), *Propulsion Trends in Container Vessels.* MAN Diesel & Turbo.

3. Simulation Model

To achieve the objectives of this study, a simulation model (Dynamic Operating Costs Evaluation Model: SDCEM) was designed based on one loop in the Asia-Europe route using System Dynamics as shown in Figure 2. The aim of the simulation was to simulate the impact of slow steaming effects on liner shipping by the deceleration of voyage speed (from 25 to 10). In this model, some assumptions were made based on the real market data published by Drewry, Alphaliner, Clarkson and Man Disel & Turbo for a more precise simulation as follows:

- The liner shipping market is a perfect competition market.
- The liner service is provided based on the weekly service patterns.
- The average vessel size on a loop is 8,000 TEU.
- The designed voyage speed on a loop is 25 knots, and liners can control their voyage speed from 25 to 10 knots on a loop.
- The number of calling port is 10, and total voyage distance is 11,600 miles.
- The bunker fuel price is 650 US$/ton (Bunkerworld, 2012).
- The average value of goods in TEU is 27,331 US$ (Drewry, 2011).
- The imperfect combustion of bunker fuel and the resistance for ships navigating are not considered.

4. Results of Simulation

4.1 Relationship between voyage speed and service organization

Slow steaming is the operational technique that operates the vessel by lower speed deliberately than designed voyage speed, and then it makes necessary to employ more vessels to transport the same volume of cargo while maintaining the announced weekly service schedule. Therefore, slow steaming leads to the increase of round trip time and the decrease of turnover ratio with maintaining the transport capacity on a loop. According to the result of simulation, for example, when voyage speed is decelerated from 25 knots to 15 knots, the round trip time per voyage was increased by 24.5 days, and the required number of vessel on a loop was also increased from 8.12 to 11.63 vessels. These relationships have influence on the operating costs directly.

4.2 Relationship between voyage speed and slow steaming effects

In simulation 2, the changes of the slow steaming effects by the deceleration of voyage speed on a loop have been simulated using a simulation model (DOCEM) as shown in Figure 3. In this diagram, four slow steaming effects, i.e. annual saving fuel cost (Positive effect), the additional fixed and variable costs (Negative effect 1), an opportunity cost (Negative effect 2) and the in-transit inventory cost (Negative effect 3) are changing separately by their own mechanisms. In the case of annual saving fuel cost curve, it is '∩' shaped, whereas other curves are '∪' shaped. On the other hand, the positive effect is larger than the sum of negative effects in the range of voyage speed between 25 and 12.9 knots, but becomes smaller from below 12.9 knots as shown in Figure 4. Therefore, it can be defined that slow steaming is helpful to reduce the operating costs only within the speed range of 25 and 12.9 knots based on the result of simulation. This result has influence on the operating costs directly.

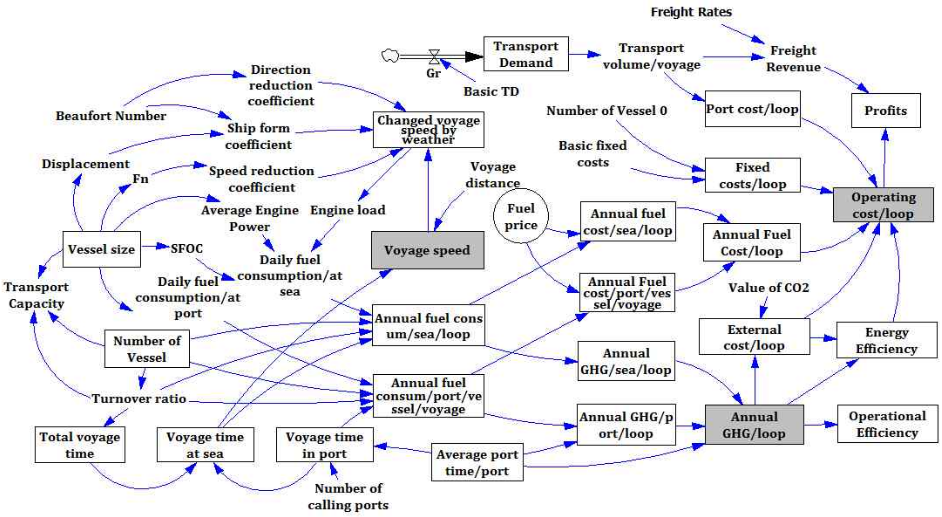
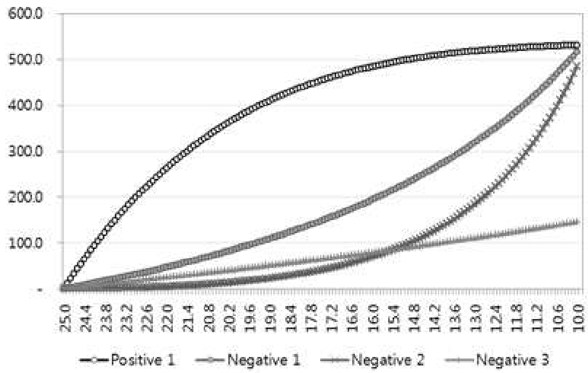
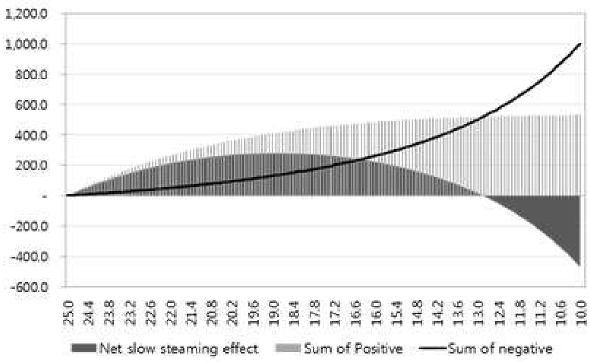


Fig. 2 Dynamic operating costs evaluation model



(Unit: Million US$)

Fig 3 Changes of five slow steaming effects at different voyage speeds



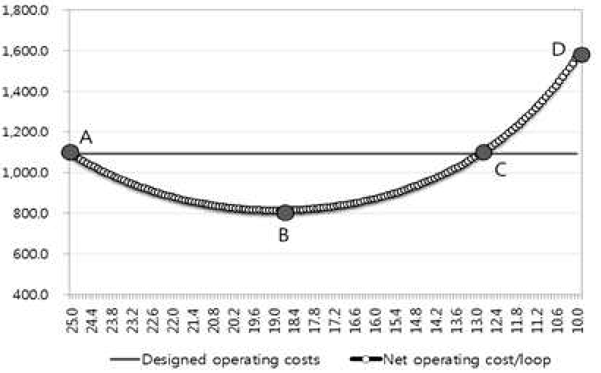
(Unit: Million US$)

Fig 4 Net slow steaming effects at different voyage speeds

4.3 Relationship between voyage speed and operating costs

In simulation 3, the designed operating cost curve and the net operating cost curve have been derived to verify the effectiveness of slow steaming and to find the best voyage speed. According to the result of simulation, the designed operating cost is fixed, and the net operating cost curve is 'U' shaped as shown in Figure 5. In this diagram, net operating cost is smaller than the designed operating cost within the range between point A and point C (25-12.9 knots), whereas it becomes larger in another range between point C and point D (12.9-10 knots).

Based on the results of the simulation, some definitions can be derived as follows. Firstly, it can be defined that slow steaming is not always helpful in reducing the operating costs on a loop. Secondly, the economic range of voyage speed is decided within the range between 25 and 12.9 knots. Therefore, liners can reduce their operating cost within this range of voyage speed using slow steaming. In contrary, when liners control their voyage speed to below 12.9 knots, slow steaming may cause the increase of their operating cost on a loop. Thirdly, the optimal operating cost on a loop is decided at point B, and the best voyage speed is also decided at 18.6 knots. The point B is the lowest point of the net operating cost curve on the condition of NOC-DEOC $\leq$ 0. Therefore, when liner shipping companies control their voyage speed at 18.6 knots, they can minimize their operating cost on a loop using slow steaming.

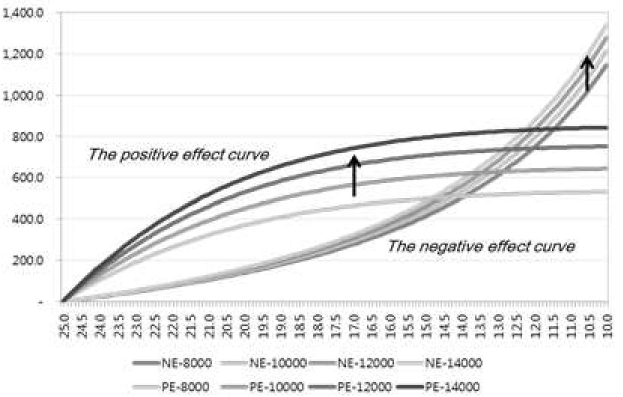


(Unit: Million US$)

Fig 5 Relationship between voyage speed and net operating cost

5. Sensitive Analysis

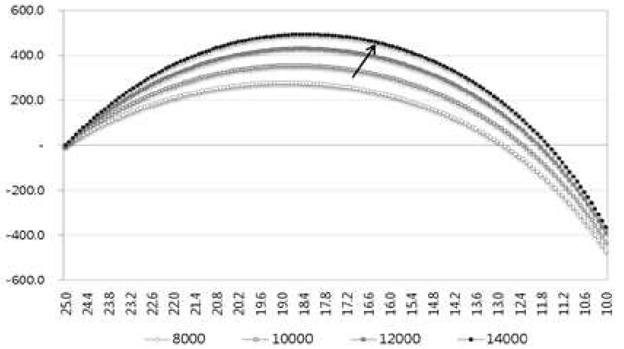
A sensitive analysis was conducted to analyze the relationship between the slow steaming effects and the economies of vessel size. As discussed above, nowadays, liners adopted slow steaming as their major operating strategy on major routes, and, at the same time, they have successively increased their employed vessel size focusing on the Super Post-Panamax ship. Therefore, if there is a positive correlation between both effects, as vessel size increases, the positive slow steaming effects increase. However, if there is a negative correlation, it is required to liners to change or improve their strategies.



(Unit: Million US$)

Fig 6 The changes of the positive and negative effects at different type of vessels

In this analysis, the changes of net slow steaming effects and the net operating cost by the increase of vessel size (8,000, 10,000, 12,000 and 14,000 TEU) have been simulated. According to the result of simulation, as the average vessel size increases, the positive effect curve and the negative effect curve shift upward each other as shown in Figure 6. Moreover, it leads not only to the increase of the scale of net slow steaming effects but also to the expansion of the economic range of voyage speed as shown in Figure 7. In this sense, it can be defined that there is a positive correlation between the increase of vessel size and net slow steaming effects on a loop.



(Unit: Million US$)

Fig 7 Net slow steaming effects at different type of vessels

6. Conclusion

In this study, the effects of slow steaming on the operating cost in liner shipping have been analyzed. Moreover, the answers to the basic questions have been derived as follows. Firstly, the operating cost on a loop is not reduced always using slow steaming. It can be reduced within the economic range of voyage speed (12.9-25 knots). However, when the voyage speed is decelerated to below 12.9 knots, the operating cost on a loop begins to be higher than the designed operating cost. In this sense, super slow steaming (15-18 knots) is also of great help in reducing the operating cost. Secondly, the best voyage speed that minimizes the operating cost on a loop is decided at 18.6 knots. Hence, when the voyage speed is decelerated from 25 to 18.6 knots, liners could maximize the reduction of the operating cost (30.8%).

Thirdly, there is a negative correlation between the slow steaming effects and total operating costs. According to the result of the simulation, as vessel size is increased, the operating cost is also increased at all ranges of voyage speed. However, from the viewpoint of slot cost, there is a positive correlation between the slow steaming and the economies of vessel size. This result tells us why some leading liners try to increase the vessel size with continuing slow steaming as their operational strategy.

Finally, when considering the results of this study, it is necessary to reconsider the concept of the Energy Effi-ciency Operational Indicator (EEOI). The International Maritime Organization (IMO) has set a goal to reduce CO_2 emissions by 20-50% through the improvement of the operating system such as voyage optimization, fleet management and energy management (IMO, 2010). To achieve this, they suggest three basic approaches; namely, the enlargement of vessel size, the reduction of voyage speed and the application of new technologies (IMO, 2010; MEPC 60/4/35, 2010). However, the outcome of the simulation shows that the increase of vessel size has a negative influence on the operating cost. Therefore, when liners adopt both the strategies of enlargement of vessel size and the reduction of voyage speed, even if the energy efficiency is increased, it can affect to the operating cost negatively.

Therefore, from the viewpoint of liners, although the reduction of GHG emissions is one of the important strategies, they do not decelerate voyage speed without economic advantages. Moreover, from the viewpoint of policy makers such as IMO and other relevant international organizations and governments, they cannot force liners to reduce the amount of GHG emissions without considering the liners' economic situation. In this respect, further studies on the relationship among the EEOI value, the operating cost and the reduction of GHG emissions are needed to improve the environmental performance and maintain the sustainable growth within the liner shipping industry.

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