Multimodal route choice in maritime transportation: The case of Korean auto-parts exporters

Abstract

Global offshoring has increased the need for transport of half-finished goods and components, along with finished goods. The auto-parts industry in Korea has also entered the global market as Korean car manufacturers have started to build overseas factories. Maintaining cost competitiveness by minimising total logistics costs will thus be a critical strategy for the industry. This research compares the total annual costs of four feasible transport routes from Korea to the US using the inventory-theoretic model, which encompasses direct transport costs, in-transit carrying costs, and warehouse inventory costs. We apply this model to real transport data collected from a Korean auto-parts company. A static analysis shows that inventory costs can play a decisive role in altering the cost competitiveness of different routes. In addition, sensitivity and scenario analyses with changes in variables and the market situations reveal that the cost structure of each routes plays an important role in determining their relative cost competitiveness in varying market conditions.

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Keywords: Auto-parts industry, Transport route choice, Inventory-theoretic model, Scenario analysis.

1. Introduction

Global offshoring has increased both the international movement of end products and the need for the transport of half-finished goods and components (Gereffi and Lee, 2012). Undoubtedly, the majority of low-tier suppliers have become heavily dependent on remote manufacturers and suppliers in the globalisation process; specifically, the auto-parts industry has entered the global market as car manufacturers participate actively in global operations (Humphrey, 2003;

Sturgeon, Van Biesebroeck, and Gereffi, 2008). Auto-parts suppliers can also benefit from involvement in global operations through economies of scale that can be realised by both aggregation and possible market growth.

Several challenges, however, emerge at the same time. Auto-parts suppliers usually depend heavily on global auto manufacturers for their operations and logistics management, which makes them vulnerable to market changes or macro policy decisions taken by large manufacturers. Taking advantage of the power they have over suppliers in their relationships, vehicle manufacturers explicitly or implicitly force suppliers to provide auto-parts to meet the time-frame of production planning. Because delay is unacceptable despite the length of the supply chain, auto-parts suppliers tend to accumulate extra buffer inventory or use expensive logistics and transportation options (Nieuwenhuis, Beresford, and Choi, 2012). In addition, suppliers are exposed to even fiercer competition in the global market than in the domestic market. They are expected to improve the quality of their products while maintaining a price level that is reasonably competitive in the global context. Whereas a long-term strategy to stay competitive in the market could be based on technological advancement or investment in facilities, the short-term option tends to be logistics-cost reductions. Therefore, having a clear and effective logistics strategy is a primary prerequisite for auto-parts suppliers in the global market.

Korea’s auto-parts industry has increased its competitiveness in parallel with the global expansion of Korean automotive manufacturers. More opportunities may have arisen since the Korean government signed free trade agreements with the European Union (EU) and the United States (US). Korean auto-parts manufacturers expect their global price competitiveness to improve, with a commensurate increase in their share of the global market, reducing their dependence on Korean automotive manufacturers as well. However, the new opportunity brings with the requirement to develop the logistics capability necessary to select the most efficient transport mode and route to minimise both transit-time and cost while satisfying customers’ expectations and norms in supply reliability. Only after their logistics systems are fully effective will auto-parts suppliers be able to take full advantage of the opportunities that will be created through these trade agreements.

A group of previous studies endeavour to solve the optimal intermodal routing problems primarily using mathematical programming such as mixed-integer programing and dynamic programing (e.g. Ayar and Yaman, 2012; Cho, Kim, and Choi, 2012; Xie et al., 2012; Xing and Zhong, 2017). These studies are based on several assumptions to model multimodal transport networks involving limitations to be applied to specific routes or industries (Wang and Yeo, 2017). Even though optimal solutions obtained from different problem settings are important in their rights, they hardly provide meaningful implications to individual firms. The other group is applications based on real-world setting using the classic economic model. The notable empirical studies that build upon the classical economic model is a series of multimodal case studies using the Beresford cost model (e.g. Beresford, 1999; Banomyong and Beresford, 2001; Beresford, Pettit, and Liu, 2011; Nieuwenhuis, Beresford, and Choi, 2012). The main drawback of this approach is in nature static and confined with the use of two-variables such as distance-cost and distance-time. Therefore it would be useful to adopt the method to compare intermodal alternatives in certain routes incorporating important variables such as direct and in-transit transport costs and inventory cost (Bookbinder and Fox, 1998; Jung, Woo, and Park, 2015). In addition it is suggested that maritime transportation route choice should be viewed from the perspective of shippers and third-party logistics firms taking multimodal transport approach into account (Bookbinder and Fox, 1998; Wang and Yeo, 2017; Sohn, Woo, and Kim, 2017).

In this study, therefore, we aim to investigate the efficient transport and logistics options for the Korean auto-parts industry in the trans-pacific transport corridor. To this end, we conduct a comparative analysis of feasible transport and logistics options from Korea to the US. We adopt the inventory-theoretic model, which takes into account direct transport costs, in-transit carrying costs, and warehouse inventory costs. Following a static analysis that compares transport options using empirical data collected from a Korean auto-parts company, we conduct a series of scenario analyses that reflect various exogenous conditions the industry could face. The next section provides a review of the auto-parts market and a theoretical background of transport mode selection. The methodology section delineates an analysis model and data collected from the industry. We then present a case study that compares four principal transport routes used by a Korean auto-parts firm whose goods are exported to Alabama and Georgia, US. In addition, a scenario analysis demonstrates the influence of different variables in the selection of transport routes. In conclusion, the implication to port authorities and terminal operating companies are discussed, and the contributions and limitations of this research are presented.

2. The Korean auto-parts industry

Globalisation has had important effects on the Korean automotive industry. The first is the movement of production facilities to the market where demand exists: often called a 'close-to-market' production strategy (Nieuwenhuis, Beresford, and Choi, 2012). Specifically, with competition in developing markets getting fiercer, global car manufacturers started to build factories in those countries in an attempt to increase their market share. As a result, some global automakers now see their overseas manufacturing exceed their domestic production (Sturgeon, Van Biesebroeck, and Gereffi, 2008). Korean manufacturers have built several factories in the countries where future demand is expected to surge to enhance their competitiveness and increase their market share. The second effect is stagnation in domestic production. Table 1 shows the production of the representative two Korean car manufacturers from 2009 to 2014. Hyundai Motors have expanded global footprints for the last decades in the US, China, Russia, India and so on and Kia Motors also has manufacturing sites in the US, China and Slovakia. The overseas production of Hyundai Motors first exceeded the domestic production in 2010 and the gap has widened with the overseas production accounting for 62% in 2014. Whereas the domestic production of Kia Motors is still more than its overseas production, the proportion of overseas production has substantially increased from 25.7% in 2009 to 43.8% in 2014.

<Insert Table 1 around here>
<Insert Table 2 around here>

We estimate that as of 2014, Korea had a total of 879 auto-parts suppliers: 231 large companies and 648 small and medium-sized enterprises (Korea Auto Industries Cooperative Association, 2015). The aggregated revenue of the Korean auto-parts industry reached USD 73 billion in 2010. The breakdown of the annual revenue is shown in Table 2. Among the three revenue sources, original equipment manufacturing (OEM), spare parts supply, and exports, the proportion of exports almost doubled between 2010 and 2014 largely through supplying for the Korean car manufacturers. In addition to exporting auto-parts, several suppliers operate their own auto-parts factories near auto manufacturers' facilities abroad. In both cases, the supply chain for Korean auto-parts firms has been lengthened, and control over the international movement of their products has become important, and in some cases critical, to profitability. In other words, selecting the most time- and cost-effective transport method and route to meet their customers' demands has become a critical issue for Korean auto-parts companies.

3. Literature review

Although models for transport mode selection can be categorised in various ways: the classic economic model, the inventory-theoretic model, the constrained optimisation model and the revealed preference model (McGinnis, 1989; Meixell and Norbis, 2008), the literature on optimal transport mode selection has three main streams. The one is research on attributes of mode/supplier selection to determine the relative salience of each factor. Ballou (1978) considers cost, time, variability of transit time, and risk of cargo loss in the selection of five transport modes such as railways, trucks, ocean, pipeline and airways. It is suggested that not only freight rate but also customer services such as reliability and punctuality of transport routes should be considered (Collision, 1984; Brand and Grabner, 1985). Recently Yang and Yeo (2017) investigate intermodal route selection factors including total cost, total time, reliability, security, and transportation capability using Fuzzy Delphi method.

The other group is studies on intermodal routing optimization using mathematical programming such as mixed-integer programing and dynamic programing. Some literature attempts to obtain general optimal multimodal networks solution in the settings of multi-objective, multimodal and multi-commodity transportation. (e.g. Ayar and Yaman, 2012; Domuta et al., 2011). Some studies focus on specific routes or cargo types (e.g. Cho, Kim, and Choi, 2012; Xie et al., 2012; Xing and Zhong, 2017; Adland, Jia, and Strandenes, 2017). These studies are based on some assumptions to model multimodal transport networks entailing limitation to be applied to specific routes or industries (Wang and Yeo, 2017). To obtain optimal solutions in different problem settings is important, but it is sometimes hard to provide meaningful implications to individual firms.

The third group is applications based on real-world setting using the classic economic model. The notable empirical studies that build upon the classical economic model is a series of multimodal case studies using the Beresford cost model (e.g. Beresford, 1999; Banomyong and Beresford, 2001; Beresford, Pettit, and Liu, 2011; Nieuwenhuis, Beresford, and Choi, 2012; Jung, Woo, and Park, 2015). This model applies a graphical cost model to real world cost and time data to intuitively compare feasible multimodal transport options. The model is an advanced version of the classic economic model in that it shows differences in solutions by reflecting the cumulative progress of time, costs, and mode changes as freight consignments proceed from origin to destination. Banomyong and Beresford (2001) broadened the scope of analysis by adding a confidence factor to the original model. That model was then expanded to include environmental factors such as CO_2 emissions (Nieuwenhuis, Beresford, and Choi, 2012), providing a clear visualisation when comparing competing multimodal options. The major contribution of their research model is that it can be broadly applied to the decision-making process for any multimodal transport route. In other words, managers can adopt this model to graphically compare the pros and cons in terms of time and transport cost or other elements, such as best versus worst performance, for any feasible transport options, current or hypothetical. Therefore, this model can also identify the 'weakest link' in a multimodal transport route.

The main drawback of this approach is in nature static and confined with the use of two-variables such as distance-cost and distance-time. Therefore it would be useful to adopt the method to compare intermodal alternatives in certain routes incorporating important variables such as direct and in-transit transport costs and inventory cost (Bookbinder and Fox, 1998; Jung, Woo, and Park, 2015). When the total cost is taken as the subject of comparison in transport choice, the inventory-theoretic model can be applied to overcome the limitations of the classic economic model. Composed of transport cost, in-transit carrying cost, ordering cost, and recipient's inventory carrying cost, this model, first formally highlighted by Baumol and Vinod (1970), embraces inventory costs as well as transport costs. It can also optimise trade-offs among service attributes such as freight rates and speed (McGinnis, 1989), allowing simultaneous evaluation of time and cost factors. Moreover, the mathematical formulae of the inventory-theoretic model provide flexible applications that reflect changing market conditions. In addition it is suggested that maritime transportation route choice should be viewed from the perspective of shippers and third-party logistics firms taking multimodal transport approach into account (Bookbinder and Fox, 1998; Wang and Yeo, 2017; Sohn, Woo, and Kim, 2017). While the inventory-theoretic model has theoretical advantages to overcome weakness of the Beresford model, empirical applications of the inventory-theoretic model to real industry data are much limited.

4. Research methods and data collection

This study conducts a comparative analysis of feasible transport options in the international logistics of auto-parts from Korea to the US using data from a case-study firm. Our analysis method in this research was primarily based on the inventory-theoretic model, which considers both transport costs and inventory costs. Because inventory costs depend largely on the transit time, this model can cover not just cost factors but also time factors interpreted in monetary terms. According to the inventory-theoretic approach to modal choice of Baumol and Vinod

(1970), the optimal choice is determined as the point of the minimum total annual cost that encompasses all expenses, including direct shipping costs, in-transit carrying costs, ordering costs, and warehouse inventory costs. Therefore, we derive the following notation:

$$\mathbf{TC = rD + icTD + s(D/q) + ic(q/2)}$$

Where
TC: Total annual logistics cost, including both transport and inventory costs
r: Transport cost per unit
D: Annual demand for the commodity transported via a specific route
i: Inventory carrying cost against commodity price
c: Commodity price per unit
T: Average transit time represented as the ratio of 365 days
s: Cost of ordering
q: Ordering amount

This formula needs to be modified, however, in consideration of several exceptional conditions in the supply of auto-parts. Firstly, because a significant amount of the ordering cost is absorbed in the transport cost in the Delivered Duty Paid (DDP) terms, we ignore the ordering costs. Secondly, auto-parts firms maintain substantial amounts of safety stock because a stock-out of auto-parts leads to a breakdown in supply, a drop in reputation, and potentially expensive claims from car manufacturers. Safety stock here means stock kept in case of uncertainties in demand and variations in lead time, which we assume to be four weeks. Therefore, the inventory-theoretic model we use in this research is:

$$\mathbf{TC = rD + icTD + ic(q/2 + 4q)\ldots\ ordering\ once\ a\ week}$$

$$\mathbf{TC = rD + icTD + ic(q/2 + 8q)\ldots\ ordering\ twice\ a\ week}$$

We collected the data through a case study of a Korean auto-parts firm that exports components to automotive manufacturers in Alabama and Georgia, US. The company operates a warehouse in Luverne, Alabama, US, but all the auto-parts are produced solely in Korea. The case of the target company is rather common for the Korean auto-part firms. Whereas around several companies operate manufacturing sites in the US, most companies that supply auto-parts to automotive manufacturers such as Hyundai and Kia Motors operate warehouses at near locations. Larger firms like Hyundai Glovis have multiple warehouses at the nearest locations to Hyundai Motors and Kia Motors, but it is common for the Korean auto-part suppliers to operate a common warehouse to serve both manufacturers in somewhere between the two manufacturers such as Luverne. Therefore this case study may represent transport routing problems of the Korean auto-parts firms for the most cases.

When transporting products from the factory to the warehouse, transport options that the company can use are four main multimodal routes, with trucking from the factory to Busan Port being the initial mode for all four routes. The first route (Birmingham Route) is a Mini Land Bridge (MLB) using railway in the USA. The containerised cargo is discharged in Long Beach Port, California, then transported via rail to Birmingham, Alabama, and then finally trucked to the warehouse in Luverne. The second route (Long Beach Route) is also a MLB, using shared trucking from Long Beach to Luverne instead. The third route (Mobile Route) is an all-water route via the Panama Canal; the cargo is discharged at the Port of Mobile, Alabama, and transported via truck from the Port of Mobile to Luverne. The fourth route (Savannah Route) is also an all-water route that uses the port of Savannah, Georgia, as the discharge port.

<*insert Figure 1 around here* >

We collected the export data over a 15 months from March 2013 to June 2014 with the full consent of the firm. During the period (65 weeks), the company supplied 770 FEUs (forty-foot container) and the annual demand is estimated to be 616 FEUs (52 weeks). The pre-transport and pre-duty value of the products in one forty-foot container (FEU) amounts to USD 67,000. For the mini-bridge routes, sea transport is conducted twice weekly by shipping company A. In contrast, for the all-water routes, the cargo is dispatched once a week. Transport to the Port of Mobile is serviced by shipping company B, whereas Savannah Port service is offered by shipping company A. The annual demand for auto-parts is 616 FEUs, and the company assumes its inventory carrying cost as a percentage of commodity prices to be 15%. The variables relating to the inventory-theoretic model in this research are summarised in Table 3.

< *insert Table 3 around here* >

Tables 4 and 5 show the average transit time, distance, and transport cost of each route. The Long Beach Route with shared trucking is both the most time-effective and most expensive route in terms of transport cost. On the other hand, the Mobile Route takes the longest time but at the lowest total cost. Given the transport time and costs, Table 5 presents allocation of cargo handled by the company for the each routes. The Mobile route is dominant with the proportion of 48.7% whereas the Birmingham and Savannah routes are employed with similar proportion of 22.7% and 19.5% respectively. The proportion of the Long Beach route is the lowest due to the highest transport costs but it is indispensable due to for the exceptional cases such as emergent orders, stock-outs and unexpected surge in demand. The allocation appears to be reasonable when the transport costs are considered only. However, the total cost reflecting the inventory costs might produce different results.

< *insert Table 4 around here* >

< *insert Table 5 around here* >

5. Empirical sensitivity analysis

In this section, we use the inventory-theoretic model to compare the transport options for the auto-parts firms exporting products from Korea to the US to determine the best transport route in terms of total annual costs. We also consider shifts in the optimal route when variable values or market circumstances change.

5.1. The optimal transport route: static analysis

For the research model, the total annual cost consists of direct transport costs, in-transit carrying costs, and warehouse inventory costs. For the mini-bridge routes, Birmingham and Long Beach, the formula is **TC = rD + icTD + ic(q/2 + 8q)** because there are two voyages per week. On the other hand, we calculate the total annual cost for the all-water routes with just one voyage per week according to the formula **TC = rD + icTD + ic(q/2 + 4q)**.

The results of this model, as shown in Table 6, are that the all-water route via the Port of Savannah (Savannah Route) is the transport option that minimises the total annual cost. Using only the Savannah Route could save the firm at least USD 44,000 per annum compared to using other routes. Although the direct transport cost of this route is higher than that of the Mobile Route, the relative advantage in the in-transit carrying cost makes up the difference, mainly through the 10-day difference in transit time. This reason also explains the narrowed cost gap between the Birmingham Route and the all-water routes, despite the big difference in the transport costs: the Birmingham Route has a distinct advantage in terms of transit time.

< *insert Table 6 around here* >

When considering the cargo volume shown in Table 5, the case-study firm's preference in transport selection seems to hinge on the service cost because they most frequently chose the Mobile Route, which had the lowest transport cost. However, that preference might be ill-judged because it completely overlooks the in-transit carrying costs, which escalate significantly with long transit times. The in-transit carrying cost is not as explicit as the transport cost, but it plays a bigger role in the total cost as lead time increases. The transit time is thus important not just to meet the importer's needs in a timely manner, but also to determine the total cost by influencing the in-transit carrying cost.

Figure 2 breaks down the total annual costs of the four transport routes into percentages for the transport cost, in-transit carrying cost, and warehouse inventory cost, highlighting the clear differences between the mini-bridge routes and the all-water routes. The mini-bridge routes have short transit times and relatively high transport costs that stem from using rail and trucks to move cargo from the West Coast of the US to the warehouse. As a result, the proportion of the total transport cost is significant — more than 80% — on both of those routes, and the in-transit carrying cost is the least important contributor to the total annual cost. The all-water routes have the opposite cost breakdown: the transport cost accounts for around 70% of the total cost, and the in-transit carrying cost is higher than the warehouse inventory cost. This figure also highlights that the inventory costs, such as the in-transit carrying costs and the warehouse inventory costs, should not be neglected because they account for between 12.4% and 30.8% of the total annual cost, depending on the transit time and order frequency.

< insert Figure 2 around here >

These results show that the cost competitiveness of the all-water routes is significantly undermined when the inventory costs are considered and the transit time increases. A comparative analysis on the original data shows that the total cost of the Birmingham Route is 14% higher than that of the Savannah Route. However, once the inventory costs are taken into account, the gap narrows to 3.25%. When the transit time of the Birmingham Route is fixed, a 5.6 day increase of transit time via the Mobile Route and an 8.2 day increase via the Savannah Route makes the Birmingham Route more cost-competitive. The mini-bridge routes have so far been regarded as the most suitable transport solution, but that is only true when the transit time is more important than the logistics cost. This result suggests that selecting one of the mini-bridge routes can be justified from the total annual cost perspective as well.

5.2. Effects of changes in variables

Just as market conditions are always changing, so is the relative importance of the key variables in international transport. In this context, the applicability of a static analysis could be limited for selecting a transport route in practice over the medium to long term. In addition, even auto-parts firms with the same origin-destination pairs as the sample firm might have some discrepancies in variable values. Hence to add value to our research, we perform sensitivity analyses of the effects of possible changes in the variables.

*5.2.1. Changes in transport cost per unit (**r**)*

The eastbound freight rate for the Trans-Pacific container route is quite volatile as shown in Figure 3. Under the Trans-Pacific Stabilization Agreement (TSA), liner companies have the authority to raise the freight rate or impose surcharges when events such as a surge in demand, an increase in oil prices, or a shortage of empty containers occurs. By contrast, a service contract, a confidential transport contract between a shipper and a liner company, often plays a role in reducing the freight rate from standard commercial market levels. As shown in Figure 2, the transport cost is the biggest issue even when the total annual cost of international logistics includes the inventory costs. In these circumstances, a change in the transport cost per unit (***r***) can significantly affect the total annual cost and alter the transport selection process in the form of a change in route, carrier, or mode.

< insert Figure 3 around here>

According to the current static data, minimising the total annual cost puts the route preference in the following order: (1) Savannah Route, (2) Mobile Route, (3) Birmingham Route, and (4) Long Beach Route. Changing the ratio of ***r*** alters the ranking. When ***r*** increases, the proportion of inventory costs in the total cost is lowered, and that of the transport cost becomes more important. Thus, with an increase in the transport cost and a reduction in the inventory costs, the Mobile Route can be selected for the minimum total cost. The analysis shows that a 35.5% increase in ***r*** can shift the shipper's selection from the Savannah Route to the Mobile Route. On the other hand, when ***r*** falls, the reduced importance of the transport cost as a component of the total annual cost gives the Birmingham Route the advantage. With a 17.2% decrease in ***r***, the Birmingham Route becomes more cost effective than the Mobile Route, and with a 32.2% decrease in ***r***, the Birmingham Routh becomes the best transport route, even ahead of the Savannah Route. Assuming ***r*** for the Savannah Route is fixed, a USD 226 drop in ***r*** makes the Birmingham Route cost competitive with the Savannah Route. The Mobile Route is the best transport route if ***r*** is reduced by USD 71. These changes are very likely to take place considering the volatility shown in Figure 3. This result implies that auto-parts distribution is sensitive to the transport cost profile of each route, which can change independently from one route to another. Although considerable correlation between the routes' cost profiles is clearly likely (e.g., by exhibiting similar wage or fuel costs), room for significant residual variations remains (e.g., in overhead costs or distance-based costs, which differ with routeing differences), implying that auto-part companies can benefit from 'route brokering'.

*5.2.2. Changes in inventory carrying cost (**i**)*

The inventory carrying cost is affected by the capital costs, insurance premiums, warehousing costs, depreciation costs, and other factors (Cook, 1983). Although it is difficult to capture a precise number for ***i***, the literature generally assumes 20% of the commodity value to be the inventory carrying cost (Beresford, 1999; Christopher, 2007). Gathering information about the inventory carrying cost from the sample firm was also challenging because that forms a part of their confidential financial and accounting information. Therefore, we take ***i*** to be 15% because a significant proportion of the insurance premium and warehousing cost is already included in the transport cost. However, ***i*** can vary across firms and be affected by other exogenous factors.

Because ***i*** influences the in-transit carrying costs and warehouse inventory costs, the effect of changes in ***i*** is the opposite of the effect of changes in ***r***. When ***i*** increases for the all the routes, the competitiveness of the Birmingham Route rises because its short transit times reduce the effects of inventory carrying costs. According to our analysis, if ***i*** increases by 18.1%, the Birmingham Route has a total cost advantage over the Mobile Route, and when ***i*** increases by 22.1%, the Birmingham Route becomes the most competitive in terms of minimising the total annual cost. In contrast, a decrease in ***i*** leads to a large cost reduction for routes with long transit times because a lower ***i*** significantly reduces the in-transit carrying costs. The Mobile Route, for instance, has the minimum transport cost but a high in-transit carrying cost, which raises its total annual cost. However, it can be the best route in terms of the total annual cost when ***i*** is lowered to 11.1%.

*5.2.3. Changes in average transit time (**T**)*

The inventory-theoretic model embraces transit time as a key determinant of the total annual cost, whereas other transport selection models regard it as just an alternative factor compatible with the transport cost. In other words, ***T*** affects the in-transit carrying cost. Slow steaming, port congestion, and bad weather are examples of external influences that increase the transit time. On the other hand, effective terminal operations, vessel innovation, and reduced idle time at the port or terminal can reduce the transit time. When ***T*** of the Savannah Route is fixed, a reduction of 2.58 days in ***T*** can make the Mobile Route better than the Savannah Route in terms of the total annual cost because lowering the transit time by 1 day can reduce the in-transit carrying cost by about USD 17,000. Considering the substantial idle time at the destination port, this time reduction is definitely achievable. Even if the ***T*** values of both routes are changed proportionately, a 26.2% cut in transit time can give the Mobile Route a competitive advantage. Time versus cost is therefore a key trade-off, but the relationships are subtle, and commercial reactions to them are, in reality, complex.

*5.2.4. Changes in the number of weekly orders (**q**)*

The warehouse inventory cost depends on order quantity, which is affected by the number of orders per week. In international transport, the frequency of deliveries is constrained by the number of voyages provided by the liner company that a shipper uses. In Korea, many liner companies provide two voyages per week to ports on the West Coast of the USA and one voyage to ports on the East Coast of the USA, and we take that into account in this research. However, in specific cases, a shipper can decide to increase the number of orders per week if there is no additional ordering cost. When one voyage is added to each route, the number of orders increases, which affects ***q***. The modified ***q***s for the mini-bridge routes and for the all-water routes become 3.95 and 5.92, respectively. The effect of changes in ***q*** is not strong enough to alter the transport selection, but the cost minimisation effect should be noticed. By adding one voyage per week, the total annual costs for the mini-bridge and all-water routes decrease by USD 168,660 and USD 437,482, respectively. This implies that, assuming no additional ordering costs, auto-parts firms can make considerable savings by increasing the number of dispatches per week.

6. Scenario analysis

The variables in the inventory-theoretic model do not change independently; rather, they change together, subject to market circumstances. We perform a scenario analysis presuming two extremes in the global economic business cycle: peak and trough conditions. The changes in the variables are the estimation based on the case firm’s historical data in the different extreme cases. In the analysis, we assess the effects of changes in the business cycle on transport demand and mode selection by systematically adjusting the variables between the two extremes.

6.1. Peak in the global economic cycle

Peaks in the pattern of global economic growth have a significant positive effect on international trade. An increase in the demand for merchandise from market growth leads not only to an upturn in commodity prices, but also to an increased derived demand for international transport. Liner companies react to this situation by raising freight rates, accelerating vessel speed, and deploying more vessels on a route. Therefore, ***r***, ***D*** and ***c*** will increase, and ***T*** and ***q*** will decrease. We postulate, using historical market circumstances that the changes in these variables will occur as shown in Table 7. Demand for auto-parts increases by 100%, but commodity prices are raised by only 20% because of the bargaining power of automotive manufacturers. However, the level of demand for shipping significantly affects freight rates, resulting in an increase in transport costs per unit of 50%. Because of the high demand for liner services, liner companies add one more voyage per week for each route, which leads to a decrease in the quantity ordered. The transit time to the West Coast of the US increases because congestion at the ports and on inland transportation routes nullifies the reductions in ocean transit time. The transit time for the all-water routes, however, can decrease by up to 7 days, despite congestion in port and in the Panama Canal, because of an increase in vessel speed and reductions in idle time at the container yard.

< insert Table 7 around here >

Incorporating those changes in the variables gives the total annual cost breakdowns shown in Table 8. As the transport cost increases in line with **r** and **D**, every route displays a 200% increase. However, the effect is more significant on the mini-bridge routes than on the all-water routes because the proportion of the total cost accounted for by the transport cost is higher for those routes. Moreover, reduced transit time is favourable in the context of the all-water routes, constraining the increase in the in-transit carrying costs compared to the mini-bridge routes. Overall, preferences in transport mode selection make little difference, but the gap in the total annual cost between the mini-bridge routes and the all-water routes increases when the global economy is growing.

< insert Table 8 around here >

6.2. Trough in the global economic cycle

As with growth in the global economy, recession also affects the variables in the inventory-theoretic model. As global demand for products decreases, commodity prices also drop, and capital costs rise *pro rata*. The liner market shrinks as economic conditions deteriorate, leading to freight rate cuts to below the break-even point. To reduce costs, liner companies adopt practices such as slow steaming and lay-up, which respectively increases the transit time and reduces capacity. In those circumstances, ***r***, ***D***, and ***c*** decrease, and ***i*** and ***T*** increase. The changes in the value of the variables are shown in Table 9. As the demand for auto-parts is reduced by 50%, the price reduces by 10% to a point where no profit is made. The cost of borrowing also increases, thereby raising inventory carrying costs to 20% of the nominal commodity value. The reduced demand for international transport would, in turn, bring about a 50% reduction in transport costs per unit to a point where the contributory margin is almost 0. Instead, liner companies implement slow steaming by deploying one more vessel into the sea route, which results in a transit time increase of 7 days.

< insert Table 9 around here >

The outcome in those market circumstances is that the Birmingham Route gains a competitive advantage on the basis of cost (Table 10), mainly because the direct costs (transport, shipping, and handling) are more sensitive and more prone to variation than the inventory costs are. Because the direct transport costs account for a significant proportion of the total cost for the Birmingham Route, the effect is a decrease in the transport costs per unit, and thus demand increases on this route.

< insert Table 10 around here >

Whether the global economic cycle is rising or falling, all the variables in the inventory-theoretic model change simultaneously. Compared to other factors, ***r*** and ***D*** change more significantly, which leads to volatility on the mini-bridge routes where the direct transport costs account for a large proportion of the total annual cost. On the other hand, changes in the other variables are limited, producing relatively small effects on the in-transit carrying cost and the warehouse inventory cost. However, what is certain is that the contrasting consequences of changes in the variables might limit the willingness of companies to implement a transport mode change. Thus, firms might choose to keep using their original choice of route (e.g., the Savannah Route) regardless of changes in the market. This implies that the logistics sector has a significant inbuilt conservatism that works against experimental commercial behaviour and appears to be risk averse.

7. Discussion and Conclusion

7.1. Implications to port authorities

Port selection is affected by various factors. From the perspective of shipping companies that directly use ports, capability of ports to service shipping companies such as facilities, IT systems, service quality and so on (Woo, Pettit, and Beresford, 2011; Tongzon and Heng, 2005). Shipping networks in ports including transhipment structure and frequency has also important role in determining ports when freight forwarders or shippers make decisions (Kang and Woo, 2017; Liu, Wilson, and Luo, 2016; Pagano et al., 2016). However freight forwarders or shippers tend to make decisions on which transport routes rather than which ports they use, considering total transport costs of alternative routes (Diz, Oliveira, and Hamacher, 2016). Therefore transport route selection involves change in port selection which may have significant impact on port authorities' management and performance.

It is also arguable that path dependence may exist because it is found that the Mobile route is the most frequently chosen route of the case-study firm even though the Savannah route generally minimises the total transport costs (Dooms, Verbeke, and Haezendonck, 2013). Port authorities, the Savannah port in particular, therefore need to adopt freight forwarders or shippers' perspective to overcome the path dependence when they promote and market themselves. Total transport cost is considered as a primary criteria of transport route selection whereas some firms pursue responsiveness focusing on in-transit time. It is suggested that ports authorities need to get more integrated into supply chains adopting supply chain integration practices (Woo, Pettit, and Beresford, 2013). Supply chain integration practices refer to 'planning and organising processes and procedures beyond its boundaries, comparing and benchmarking performance of services, scrutinising more efficient routes and process, and producing new service packages and marketing them to customers' (Woo, Pettit, and Beresford, 2013). Port authorities need to target at shippers which can take advantages in cost efficiency from using their ports.

7.2. Conclusion and contribution

The Korea auto-parts industry has limited experience operating in a globalised environment; rather, it has focused primarily on maximising revenue from component exports. Comparative analyses of transport routes that the industry commonly uses to export goods to the US are thus timely. In particular, the inventory-theoretic model illuminates the importance of inventory costs, which have been overlooked, because inventory costs can be a decisive factor in selecting an appropriate transport route. Our study also shows how changes in input variables, and in the global economy, can affect transport choices.

The contributions of our study to the literature are as follows. Firstly, we adopted the inventory-theoretic model for an empirical analysis of transport mode and routeing choices. Compared to classical economic models that consider only transport costs, our model considers both transport costs and inventory costs. In other words, we convert the transit time into a tangible cost term, making it possible to compare several routes using one cost measure. This model has shed light on the importance of time in transport choice by showing how transit time can influence the total annual cost structure. Secondly, we applied the inventory-theoretic model to real transport data. Unlike classic economic models, which have a strong empirical research stream, the inventory-theoretic model has been applied to empirical research to only a limited degree despite its long history, perhaps because the main objective of managing day-to-day international transport operations is reducing direct transport costs. When the perspective is widened to a firm level, however, the in-transit and warehouse inventory costs are significant additions to the direct transport costs. We have shown that the transport choice can be altered when the inventory costs and changes in variable costs are considered. Thirdly, we conducted both static and sensitivity analyses on transport choice. Because the transport and product markets are ever-changing, a static analysis that confines itself to specific circumstances is limited in its ability to explain selection mechanisms. We conducted sensitivity and scenario analyses by altering the variables and market circumstances and demonstrated that the cost structure of transport routes plays an important role in determining their relative cost competitiveness in varying market conditions.

Our research also has several wider implications for management. We compared four feasible transport routes that Korean auto-parts firms have available to export their products to assembly plants in the US. Firms generally have a strategy that encourages selective use of routes depending on the circumstances. However, transport route selection is usually made based on the total annual cost, unless other transport factors are more important in the circumstances of a given time. Secondly, our research shed light on the inventory costs that auto-parts firms must consider in the process of transporting goods. From a lean supply chain perspective, inventory creates intangible costs and uncertainties. However, the importance of accounting for inventory, especially while goods are being transported, is often overlooked. The sample company in this research accumulated substantial inventory costs in the long-haul movement of auto-parts from Korea to the US and in warehouse requirements to hold components prior to final supply. But the company's transport route preferences suggest that those costs were barely considered. Applying the inventory-theoretic model gives the firm an opportunity to consider inventory cost as a main element in its transport operations. Lastly, our sensitivity and scenario analyses showed that the best transport choice can change when the relative importance of the respective variables changes. Management must consider changes in variables such as the transport cost per unit, inventory carrying cost, and transit time because they can make a significant difference to the total annual cost for each route.

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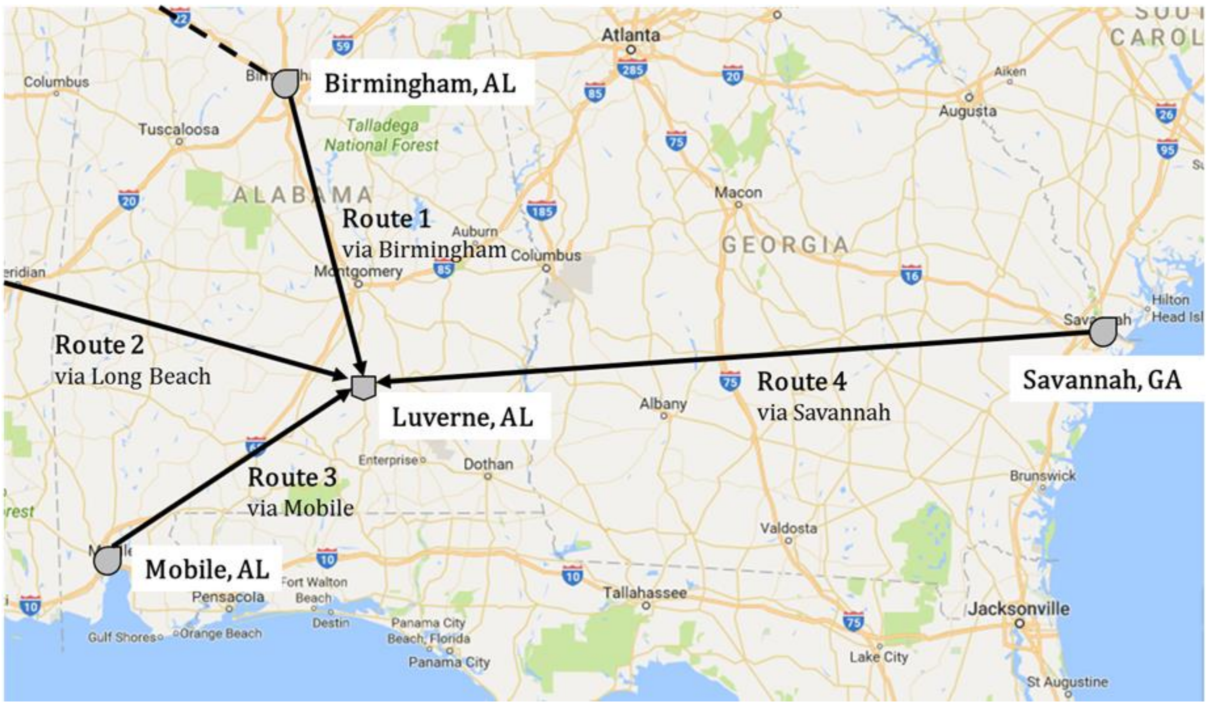
Figure 1. Illustration of the four routes



Source: The maps were drawn by the authors with the capture of Google map.

Figure 2 - The proportion of each cost in the total annual cost

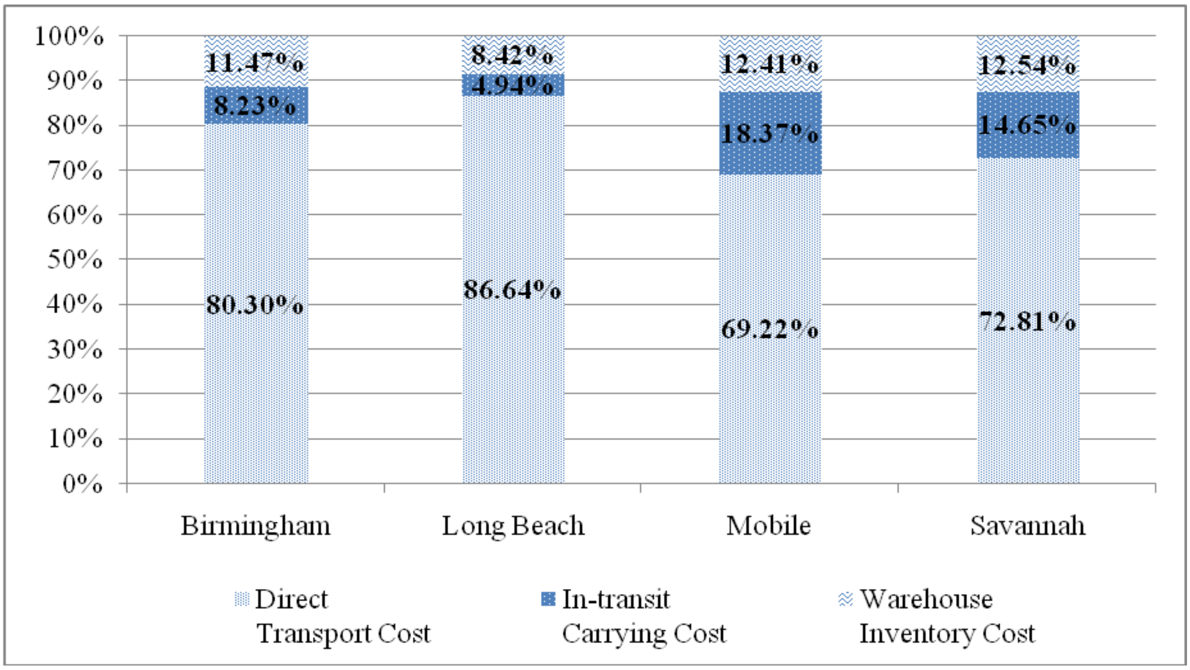
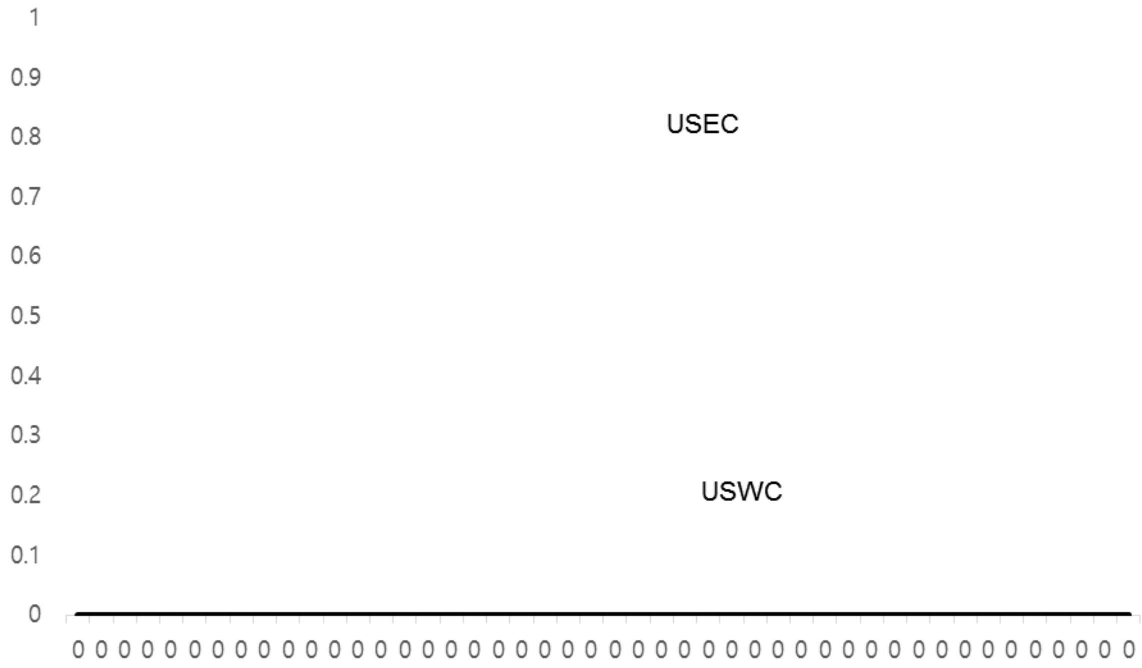


Figure 3. Volatility of Ocean Freight Rate (Shanghai Container Freight Index)



Note: USEC: The US East Coast Container Service, USWC: The US West Coast Container Service

Table 1. Overseas manufacturing of the Korean car manufacturers

(Unit: Thousand unit)

		2009	2010	2011	2012	2013	2014
Hyundai Motors	Korea	2,746(59.3%)	1,743(48.1%)	1,892(46.4%)	1,905(43.3%)	1,851(39.2%)	1,876(37.9%)
	Overseas	1,885(40.7%)	1,883(51.9%)	2,182(53.6%)	2,496(56.7%)	2,874(60.8%)	3,079(62.1%)
	Total	4,631(100%)	3,626(100%)	4,074(100%)	4,401(100%)	4,725(100%)	4,955(100%)
Kia Motors	Korea	1,137(74.3%)	1,417(66.2%)	1,584(62.3%)	1,586(58.2%)	1,599(56.5%)	1,713(56.2%)
	Overseas	394(25.7%)	722(33.8%)	959(37.7%)	1,138(41.8%)	1,233(43.5%)	1,337(43.8%)
	Total	1,531(100%)	2,139(100%)	2,543(100%)	2,724(100%)	2,832(100%)	3,050(100%)

Source: Annual reports of the two companies of 2009-2014

Table 2. The trend of annual revenue in the Korean auto-parts industry

(Unit: Million USD)

Year	Revenue				Growth Rate
	OEM	Spare Parts	Export	Total	
2010	41,980	2,519	11,551	56,050	32.1%
2011	49,171	2,950	12,468	64,589	15.2
2012	49,498	2,875	18,995	71,463	10.6
2013	48,319	2,899	20,049	71,267	-0.3
2014	49,523	2,971	20,558	73,052	2.5

Source: Korea Auto Industries Cooperative Association (2015)

Table 3. Values of variables

Variables	D	i	c	q (MLB)	q (all-water)
Values	616	0.15	67,000	5.9231	11.8462

Note: q(MLB)=616/104, q(all-water)=616/52

Table 4. Average transit time of the four transport routes

(Unit: Day)

Transport Route	Door-Port	Port	Sea	Port	Rail	Rail Depot	Door Delivery	Total
Birmingham	0.1	3.36	9.43	2.26	4	2.06	0.2	**21.41**
Long Beach	0.1	2.61	9.43	2.21	-	-	3.14	**17.49**
Mobile	0.1	4.98	28.83	12.63	-	-	0.2	**46.74**
Savannah	0.1	3.4	22.5	10.5	-	-	0.4	**36.9**

Table 5. Distance and transport cost of the four transport routes

(Unit: km, USD, FEU)

Transport routes		**Door to port**	**Port to Port (Rail CY)**	**Door Delivery**	**Total**	**Cargo allocation**
Birmingham	Distance	132	11,750	227	12,109	175
	Cost	484	4,750	516	5,750	(22.7%)
Long Beach	Distance	132	8,500	3,480	12,112	70
	Cost	484	2,350	5,616	8,450	(9.1%)
Mobile	Distance	132	16.900	243	17,275	375
	Cost	484	3,700	666	4,850	(48.7%)
Savannah	Distance	132	15,800	597	16,529	150
	Cost	484	3,500	1,066	5,060	(19.5%)

Table 6. Total annual cost and cost breakdown

(Unit for costs: USD)

Variables	Birmingham	Long Beach	Mobile	Savannah
r	5,750	8,450	4,850	5,050
D	616	616	616	616
i	0.15	0.15	0.15	0.15
t	0.0587	0.0479	0.1281	0.1011
c	67,000	67,000	67,000	67,000
q	5.9231	5.9231	11.8462	11.8462
Direct Transport Cost	3,542,000	5,205,200	2,987,600	3,110,800
In-transit Carrying Cost	363,137	296,650	792,762	625,864
Warehouse Inventory Cost	505,979	505,979	535,742	535,742
Total Annual Cost	**4,411,116**	**6,007,828**	**4,316,104**	**4,272,407**

Table 7. Presumed changes of variables in the boom period

Variables	***r***	***D***	***c***	***T***	***q***
Changes	50% ↑	100% ↑	20% ↑	7 days ↓ (all-water)	1 more voyage

Table 8. Total annual cost and its breakdowns in the boom period

(Unit: USD)

Costs	Birmingham	Long Beach	Mobile	Savannah
Direct Transport Cost	10,626,000 (200% ↑)	15,615,000 (200% ↑)	8,962,800 (200% ↑)	9,332,400 (200% ↑)
In-transit Carrying Cost	871,529 (140% ↑)	711,959 (140% ↑)	1,617,681 (104% ↑)	1,217,128 (94% ↑)
Warehouse Inventory Cost	809,566 (60% ↑)	809,566 (60% ↑)	642,891 (20% ↑)	642,891 (20% ↑)
Total Annual Cost	12,307,095 (179% ↑)	17,137,125 (185% ↑)	11,223,372 (160% ↑)	11,192,419 (162% ↑)

Table 9. Presumed changes of variables in the recession period

Variables	***r***	***D***	***c***	***i***	***T***
Changes	50% ↓	50% ↓	10% ↓	20%	7 days ↑

Table 10. Total annual cost and its breakdowns in the recession period

(Unit: USD)

Costs	Birmingham	Long Beach	Mobile	Savannah
Direct Transport Cost	885,500 (75% ↓)	1,301,300 (75% ↓)	8,962,800 (75% ↓)	9,332,400 (75% ↓)
In-transit Carrying Cost	289,119 (20% ↓)	249,226 (16% ↓)	746,900 (31% ↓)	777,700 (29% ↓)
Warehouse Inventory Cost	303,587 (40% ↓)	303,587 (40% ↓)	321,445 (40% ↓)	321,445 (40% ↓)
Total Annual Cost	1,478,206 (66% ↓)	1,854,114 (69% ↓)	1,615,239 (63% ↓)	1,545,901 (64% ↓)