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FREIGHT MODAL SHIFT MODELS ANALYSIS

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Abstract: **This paper is aimed at analyzing freight modal shift with respect to different policies that have been adopted by various government agencies so as to realize freight modal shift and also the different models that have been developed to evaluate and to ensure this modal shift. Some few models were reviewed and their approach and results were analyzed. Recent concerns have been raised that some modes of freight transport have become less environmental friendly hence the urgent need for a modal shift which has led to freight modal modelling and adoption of policies so as to realize this goal.**

Keywords: **Freight mode shift, Model, Transport modes, Road, Rail, Inland waterways, Subsidy policy.**

1. INTRODUCTION

There has been a recent demand to make transportation modes to become more environmentally friendly because of the concerns of the amounts of Green House Gases that are being emitted by these various modes of transport. Studies and research have shown that the road transport mode has the highest emission rate and coupled to that, it causes other major problems such as congestions, noise pollution in cities around residential areas, it poses safety concerns due to a high rate of road accidents. This has resulted to a higher pressure on some government agencies to introduce policies that will help with modal shifts especially from the road to the other modes of freight transport being the rail, sea/ inland waterways, air and pipelines respectively with the rail and water mode of transport considered more favourable. To achieve this, models have been developed and tested in different scenarios and impeccable results have been realized which has seen freight modal shift from road to rail.

2. LITERATURE REVIEW

It is important to note that the modal split for freight transport varies greatly by region, and the major factors that account for this are mainly economic and geographical factors. However, road transportation modes are widely used, rather than rail and water transport. Rail and water transportation modes have a substantially better environmental profile but are limited by longer delivery times and the necessity of pre- and post-haulage by truck, i.e. inter-modal transport. The reason why road transport is still widely used is that most supply chains deal with fast moving consumer goods means that a fast and efficient means of delivery is required. The inclusion of social cost in freight prices, improved energy efficiency of ships and substantial investments in rail infrastructure are required to induce a modal shift.

Economic activities are one of the major factors that have led to a high demand for freight transportation, and in many countries growth of demand outstrips GPD growth (Essen, 2009). The different modes that these freights are transported include rail, road, waterways, pipelines and by air.

When we consider modal shift between the different modes of transportation, it is important to consider the fact that, different transport markets and served by different transport modes. When goods are being transported by sea it takes a

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longer time when compared to rail and road, while the value per road transport for certain goods can also be explained by the need to be flexible and the trend towards 'delivery on demand'. Rich et al (2009) investigate this so-called structural inelasticity, i.e. the cases where substitution between modes is not possible, and conclude that particularly for origin-destination pairs below 500 km this inelasticity is very significant.

3. MODELS AND POLICIES AIMED AT INDUCING FREIGHT MODAL SHIFT

Until recently, there has not been enough research that has been done on freight mode shift modelling but however, some models have been discussed and some governments have put forth policies that have induced some percentage of modal shifts from road transportation to the other modes of transport. Burkhardt and Toshinori (2015) examine some criteria to support a modal shift provided by the Maco Polo Program and looked at the available policies such as funding aid for constructing access roads to intermodal terminals, adding criteria such as traffic flows (trucks/day) and port capability(TEUs/year) for a subsidy. Macharis and Pekin (2009) analyzed the market areas of the terminals with subsidy scenarios, such as no rail subsidy, with the barge subsidy fixed amount. Joruquin and Beuthe (1996) analyzed the different cost structures and the different operations of the different European railways and pointed out that the railway traffics are characterized by cross-subsidies between traffics. Ballis and Golias (2004) suggested that the growth of intermodal growth in Europe is supported by systematic promotions and subsidies received by European countries.

Woodburn (2003) examined the consequences of the changes in the supply chain with respect to a modal shift from road to rail. He points out that partners in a supply chain switch to rail when the supply chain was affected by changes, such as rail service quality improvements, an increase in the tax of road haulage, road pricing introduction, improvements and efficiency of rail service cost, an increased in the level of road congestion and an improvement in the accessibility of rail networks. He suggests that rail network capacity and capability improvement can help promote this modal shift. Nozick and Morlok (1997) developed a model for medium-term operation planning in an intermodal rail-truck service with the aim of optimizing systems resource such as labour, capital and energy under system's operational constraints. They addressed services such as road haulage, terminals and rail line haul. Lan and Lin pointed the significance of expediting the processing of freight at terminals with fast loading and unloading facilities working together with modern intelligent transport technologies can make rail service more compatible with a trucking service. In their developed model, Abdelwahab and Sergious (1992) found that if a consignee or a shipper is currently using a truck, then the overall effect of an increase in truck freight charges might lead to a decrease in that shipper's shipment size, thence will eventually lead to a preference for rail (due to the possibility of a reduction in the probability of using trucks).

Ishfaq and Sox (2010) explore strategic planning for an intermodal logistics network, which is operated by a logistics service provider. They showed that there are significant differences between intermodal logistics networks and traditional road logistics networks when looking at hub locations and network structures which are more prone to changes with respect to service requirement and cost. They're main focused was based on the design of a hub-based logistics network and they suggested a long-term policy in connection to the location of the hub, shipments routing, the modal choice and also looking at resource requirement planning at a strategic planning level. The main function of this hub is to conduct interregional logistics activities which are conducted between origins and destinations by the use of different transport modes such as road, rail and air. Shipments have to be strategically managed within reasonable time frame and cost because supply and demand areas are geographically dispersed. A variable option can be to develop an effective and efficient intermodal logistics network.

Baumol and Vinod (1970) utilized the inventory theoretic framework, which implies the total logistics cost (TLC) in the supply chain, as being affected by the modal choice decision. The TLC is based on parameters such as annual volume, average daily demand, holding costs, transportation cost, average lead time and value of goods.

Bu-lin Choi and Kyung-Yong Chung (2014) established a model known as the structural equation model with of aim of describing the impact of policy measures on promoting modal shift and to clarify its directivity. They came up with the following hypothesis.

H_1: Subsidy, tax and pricing have positive effects in promoting a modal shift.

H_2: Subsidy, tax and pricing have a positive effect on improving services.

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H_3: Services have a positive effect on promoting a modal shift.

H_4: Services have a positive effect in establishing strategic planning and operation.

H_5: strategic planning and operation have positive effects on building infrastructure.

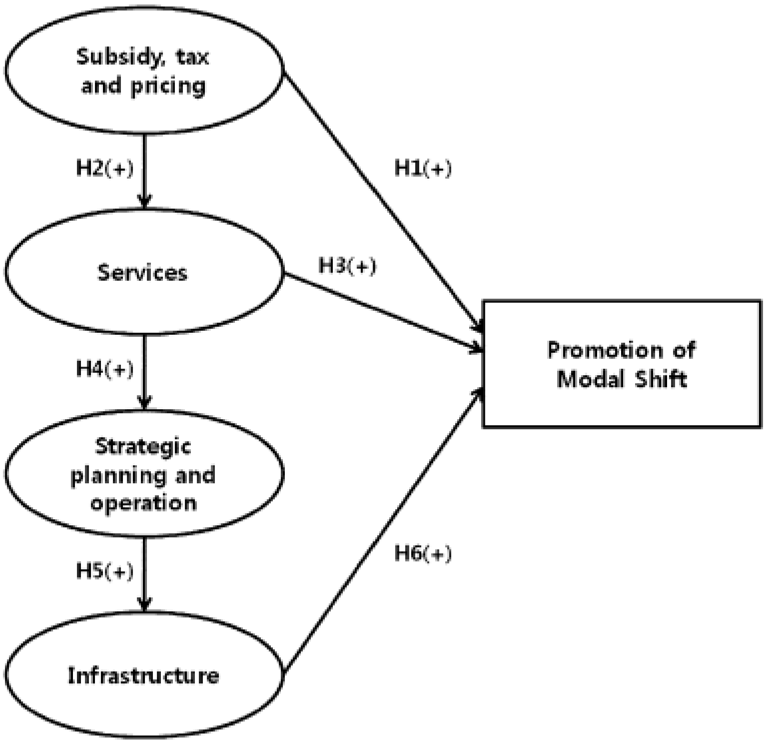

Figure 1: a policy measures framework

They carried out a survey of 205 professionals so as to examine the impact of policy measures on modal shift promotion. They had to test the research framework with the sample data collected, by first verifying the normality of the data and then testing it for each variable with skewness a kurtosis and confirmed multivariate normality to develop the structural model that describes the impact of policy measures on promoting modal shift. The results of testing the hypothesis showed that for H_1, subsidy, tax and pricing had positive effects on promoting a modal shift. The results for H_2 showed that subsidy, tax and pricing have an effect on improving services. Travel time and cost were considered as major variables in choosing transfer modes. H_1 & H_2 showed subsidy had a direct support in rail network capability and capacity improvement that reduced travel time. A tax on road haulage and road pricing promote the modal shift from road to rail by affecting costs in road freight transport. They suggested that a drop in travel time and cost attracted customers to change from road to rail. The result from H_3 showed that services had a positive effect on the promotion of modal shift. Hence, the improvement in rail service attracts stakeholders in a supply chain, like freight forwarders and consigners to switch from road to rail transport modes. The results from H_4 showed that services produce positive effects on establishing strategic planning and operation. Results for H_5 showed that strategic planning and operation has a positive effect on developing infrastructure. H_6 results showed that infrastructure has a positive effect on the promotion of a modal shift. Based on the results of test H_4, H_5 and H_6, they confirmed that services require providing reasonable rail networks and infrastructure through planning and operation and these, in turn, need to build appropriate infrastructure, which attracts freight transportation from road to rail.

Xuezong Tao (2013) in his paper “A model to evaluate the modal shift potential of subsidy policy in favor of sea-rial intermodal transport” developed an analytical tool model to assess the modal shift potential (MSP) of subsidy policy in favor of sea-rail intermodal transport (SRIT) between Ningbo Port and East Jiangxi province. Based on random utility theory and stated preference experiments, two disaggregate models, a mixed multinomial logit (MMNL) model and an MNL model, were established and estimated.

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Winston (1981) firstly developed a disaggregate model based on Random Utility Maximization (RUM) with the aim to determine the actual behaviour of freight transport decision-makers. This lead to the increasing usage of aggregate mode choice models for the analyzes of freight transport mode (FTM) choice decisions. Efforts were made to increase the range of factors that could influence the choice outcomes such as transport/non-transport cost, service attributes. The most widely used model form was the multinomial logit. All though the MNL model is seemingly popular, some researchers recognized that, in virtue of its independence from the irrelevant alternative property, it imposed that the limitations on the nature on the choice processes it could take are unrealistic. Attempting to solve this problem, Jiang et al (1999) suggested the use of a nested logit (NL) model.

Nonetheless, most of the above studies have focused on competition between modes on national or international non-maritime shipments; applications looking at the mode choice determinants in the inland transportation of containerized cargos via seaport are limited. Even if some researchers differentiate container traffic in their analysis of intermodal traffic (Jiang and Calzada 1997; Beuthe and Bouffioux 2008), those studies do not yield specific conclusions regarding door-to-port or port-to-door traffic.

To assess the MSP of different degree of subsidies in favour of SRIT between the port of Ningbo and Shangrao city, Xuezong's paper established an MMNL model and an MNL model based on random utility theory and SP techniques.

The model was expressed with the following equations;

$$U_i(m) = V_i(m) + \varepsilon_i(m) = U(x_{im}, s_i, \beta_i) = V(x_{im}, s_i, \beta_i) + \varepsilon_i(m)$$

The equation above assumed that a shipper or a consignee's decision to choose a mode is based on the highest utilities among freights. It is difficult to completely observe their utility hence the decomposition into observable and unobservable components. Where; *i* is assumed to select the Freight Transport Mode*m* for a specified shipment with the highest utility $U_i(m)$ from amongst available freight in a choice set M_i. x_{im} is a vector of the measurable attributes characterizing FTM *m* given by decision-maker *i*, s_i is a set of socioeconomic attributes of the decision-maker *i* that may also affect utility and b_i is a vector of parameters called tastes of the decision-maker *i*.

The choice probability was expressed as follows;

$$P_i(m|M_i) = \frac{e^{V_i(m)}}{\sum_{h \in M_i} e^{V_i(h)}}$$

The utility function of the model was expressed as;

$$U_i(m) = U(x_{im}, s_i, \beta_i) = V(x_{im}, s_i, \beta_i) + \varepsilon_i(m) + \eta_i(x_{im}, s_i, y|\phi)$$

And;

$$P_i(m|M_i) = \int_{\eta_i} L(\eta_i) f(\eta_i|\phi) d\eta_i$$

Where $L(\eta_i)$ is a logit choice probability conditional on a vector of parameters η_i that are jointly distributed with density $f(\eta_i|\phi)$

The results show that all attributes have the expected sign and the MMNL model outperforms the MNL model. A negative sign for the cost and time indicated that the overall marginal will be reduced with the increase of cost and time, but this is opposite of punctuality and safety. In view of the restrictions of transport infrastructure and management system in the short time, making subsidy policy to indirectly reduce shipper's transport cost becomes an effective means of achieving a modal shift from RT to SRIT since the total MSP increased with the number of subsidies to shippers. Specifically, a 100 RMB/TEU increase in subsidy resulted in an average of 1.73% increase in MSP. It revealed that to achieve a cost-effective modal shift, giving a subsidy of 400RMB/TEU to shippers who use SRIT will be a relatively optimal choice.

Other models such as the AHP model and Game Theory models like Two-player game (TPG) (Game with complete information) and Random Demand (Game with Incomplete Information) has all been used to determine modal shift from inland waterways and coastal shipping to rail from Thunder Bay, On to Toledo, OH on the amount of tons shipped looking at two scenarios being Canadian wheat and American wheat. The aim of these models was to prevent or reduce pollution of the ecosystem of the great lake from ships ballast water which endangered massive marine organisms. These models looked at the behaviours of the different players with regards to policies that could increase the cost of ballast water treatment such as ballast water exchange, filtration/UV, Heat and also looking at another alternative mode of transport. The result of the model showed that modal shift would happen if the ballast water treatment methods are mandated without financial incentives. Hence it is advisable to apply mandatory ballast water treatment requirements for the ships entering the great lake from overseas. Further investigation in modal shifts involving other cargoes (iron ore, coal) has to be carried out and also developing a model studying the change supply location.

Another model that has been used to determine modal shift along the U.S West Coast is the Geospatial Intermodal Freight Transport (GIFT) model with cargo flow analysis. The aim of the model was to analyze the energy and environmental impacts of freight movement through California's marine, highway and rail systems. The model employed a Geographic Information System (GIS)-based model with the integration of three transportation network models (road, rail, water), joined by intermodal transfer facilities (ports, railyards, truck terminals) in a single intermodal network modified to capture the energy and environmental attributes. A case study was formed to explore the different emission levels under Least-travel-time versus least CO_2 routing to the movement of freight through three major California ports (Los Angeles, Long Beach and Oakland), identifying how emission savings can be achieved through a modal shift from road to rail. Using the GIFT model with California-specific data on the transportation network, intermodal facilities, vehicle performance (energy, emission, operating cost), and freight flow (origin, destination and volumes). It was found that the least-time routes were dominated by truck traffic along parts of interstates. The model estimated a total of approximately 2.9 million metric tons (MMT) of CO_2 emission occurs over the course of the year due to freight moving in and out of these three ports on the West coast (assuming that all freight moves by truck). Out of all these, the highest levels of emissions (~ 70% of total) were due to traffic moving in and out of the port of Los Angeles-Long Beach.

In effect, the total accumulated emissions along a route consisting of an origin point and a destination point can be summarized by the following equation where E_p is the total pollution of pollutant *p*, $TE_{i,p}$ is the transfer facility emissions penalty at transfer facility *i* for pollutant *p* and is summed over all transfers *i;*1_j is the length of segment *j* in miles; and $EP_{j,p}$ is the emission factor for pollutant *p* and segment *j* in grams/TEU-mile.

Equation

$$\text{Ep} = \sum_i TEi,p + \sum_j lj.EPj,p$$

The emissions counted on a per TEU-mile basis are obtained for the three different modes depending on the vehicle attributes specified by the user through the emissions calculator or user-entered emissions rates. When optimizing for a particular emission, the travel routes are so selected that the accumulated emissions are minimized.

In the least CO_2 scenario, most freight was routed through the rail network because of low emissions involved with moving freight by train. An estimation of a total reduction of 1.7 MMT occurs through a nationwide shift of west coast port-generated goods movement within California state air basins, this reduction is near 0.5 MMT CO_2. Overall effects are promising but limited; more research is needed to determine the overall opportunities for mode-shifting.

As opposed to modelling, policies have been put in place by various governing agencies to ensure a modal shift from road to air, water and rail. Some examples include the Marco Polo projects put in place by the European Commission which aimed to realize a modal shift from road to another more environmentally friendly form of transport by providing grants to freight transport companies within the Eurozone. The EC White paper has also set a distance limit of 300km for freight shipment by trucks (EC, 2011) which mean trucks can only carry freight within a 300km distance and this has translated to a 30% shift from road to rail and waterway navigation. In the US, a lot of projects have been undertaken such as the National corridor development linking the West Coast ports and the East coast ports through a continental railway, also the National Highway System i.e. intermodal freight connectors which connected the roads network to seaports, airports and major intermodal terminals so as to enhance modal shift. Ultimately, connectors to 517 freight terminals- port, rail,

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pipelines and 99 major freight airports were selected for enhancement and improvement with a high level of information technology and intelligent transport system. In Asia, some countries like Singapore, Korea and Japan have developed well defined comprehensive logistics policies which deal with modal shifts. The Japanese logistics policy for example proposed a wide range of actions and improvements which were designed to strengthen Japan's national and international logistics base which offered convenient and attractive services in the Asia-Pacific region, where businesses and companies could profit from efficient logistics services and the general public should benefit from improved environmental and social framework conditions. This led to a modal shift from road to rail & coastal shipping in 2000 and 2002 with a percentage of 39.6% and 38.6% respectively. In China, there has been a huge investment in the different modes of freight transport. From the literature review, one of the reasons for freight transport has to deal with the demand for freight and the supply of the freight which can be influenced by economic conditions of various countries. For the last decade, China has experienced a high level of industrialization which has translated into high demand and supply for transport freight. Hence, the heavy investments in the various transport modes. Obviously, this has contributed to the high level of congestion with Chinese cities, high levels of pollution. Most Municipal governments have adopted policies to deal with this issues such as time limit for a heavy truck to operate in the cite areas so as to deal with congestion, some roads have weight and height limits. According to the experience of developed countries, the achievement of model shift needs the support of subsidy policy.

Policies and measures to incentivize modal shift include (TEMS, 2008; Essen, 2009; NTC, 2008):

•Speed limits for trucks

•Spatial planning

•Transport pricing: inclusion of external cost in freight transport, e.g. by emission trading

•Investments in road-rail-water intermodal infrastructure

•Improved energy efficiency of ships

4. ANALYSIS OF THE DIFFERENT MODELS

From the literature review, it is obvious that there is an urgent need for freight modal shift from road to the other modes of transport. Government agencies are bringing forth policies to realize this goal and models have also been developed to determine how freight modal shift can be achieved successfully. The question now is why is there so many efforts being put to realize this modal shift. This is due to the sudden need to make transportation to be more environmentally friendly. Hence, to deal with congestion, noise, air pollution from the emission of CO_2 etc.

Governments try to achieve modal shift by proving funds and subsidies especially in Euro and in the U.S. This has shown some positive effects as there has been some significant switch from road to rail and inland waterway due to grants and incentive. However, despite some of these grants, some shippers still want to use the road mode of transport as they find it more convenient and reliable. This means that governments have to do more rather than just grants and subsidies. However, some governments put forth policies that make road transportation less favourable for some transport operators such as truck weight restrictions, specific times that they can have access to roads, limited speed etc. All these policies have made some significant modal shift. But is this enough to achieve the goal to make transportation become environmentally friendly? It is interesting to note that while most governments are putting into place policies to ensure modal shift from road to rail and inland waterways, other governments are putting into place policies to ensure modal shift from inland waterways to rails and road so as to prevent water pollution from the ballast tanks of vessels which could endanger marine organisms.

Ensuring modal shift does not only depend on government agencies but also on state holders within certain supply chains. Partners in a supply chain switch to the rail when the supply chain is affected by changes, such as rail service quality improvements, increase road haulage tax, the introduction of road pricing, rail service cost improvements, increased road congestion and rail network access improvement. Therefore if major states holders within a supply chain can improve on information technology, employees' expertise, modernize terminals with the adequate equipment are within the rail, seaports and airports, then there will be a significant shift from road to these modes of transport. This is going to speed up the processing of freight at terminals with fast loading and unloading facilities working together with intelligent transport technologies will make a rail service more compatible with a trucking service.

Policies cannot be fully realized without the use of models. Some models have been developed to ensure modal shift. Some of these models have been successful and some have been criticized. The structural equation model developed by Bu-lin Choi and Kyung-Yong Chung showed that subsidy, tax and pricing had positive effects on promoting a modal shift. Hence, subsidy, tax and pricing have an effect on improving services. Travel time and cost were considered as major variables in choosing transfer modes. Their results showed subsidy supports directly the improvement in rail network capability and capacity that reduces travel time. A road haulage tax and road pricing promote the modal shift from road to rail by affecting costs in road freight transport. They suggested that a drop in travel time and cost attracted customers to change from road to rail. Their results also showed that services produce positive effects on promoting modal shift. Hence, the improvement in rail service attracts stakeholders in a supply chain, like freight forwarders and consigners to change the mode of shipment from the road to rail. These services produce positive effects on establishing strategic planning and operation which leads to a positive effect on developing infrastructure. They confirmed that services require providing reasonable rail networks and infrastructure through planning and operation and these, in turn, need to build the right logistics infrastructure, which attracts freight transportation from road to rail.

Xuezong Tao’s analytical tool model which was developed to evaluate the modal shift potential of subsidy policy in favor of sea-rail intermodal transport between Ningbo Port and East Jiangxi province showed that based on random utility theory and stated preference experiments, two disaggregate models, a mixed multinomial logit (MMNL) model and an MNL model, were established and estimated. The results from the model showed that a 100 RMB/TEU increase in subsidy resulted in an average of 1.73% increase in MSP. It revealed that to achieve a cost-effective modal shift, giving a subsidy of 400RMB/TEU to shippers who use SRIT will be a relatively optimal choice.

On the contrary, while models are being developed to ensure modal shift from road to inland waterway and rail, other models such as the AHP and Game Theory models have been used determine modal shift from inland waterways and coastal shipping to rail from Thunder Bay, On to Toledo, OH on the amount of tons shipped within these modes. The aim of these models was to prevent or reduce pollution of the ecosystem of the great lake from ships ballast water which endangered massive marine organisms. To juxtapose these models with the other models, there seems to be a paradox.

However, when we look at the Geospatial Intermodal Freight Transport (GIFT) model with cargo flow which seeks to analyze the energy and environmental impacts of freight movement through California’s marine, highway and rail systems, it shows a more diverse way of ensuring modal shift. The model employed a Geographic Information System (GIS)-based model that integrates three transportation network models (road, rail, water), joined by intermodal transfer facilities (ports, railyards, truck terminals) in a single intermodal network modified to capture energy and environmental attributes. The model explored the difference in emissions under Least-travel-time versus least CO2 routing to goods movements through three major California ports (Los Angeles, Long Beach and Oakland), identifying how emission savings can be achieved through a modal shift from road to rail. It was found that the least-time routes were dominated by truck traffic along parts of interstates. The model estimated a total of approximately 2.9 million metric tons (MMT) of CO2 emission occurs over the course of the year due to freight moving in and out of these three ports on the West coast (assuming that all freight moves by truck). Of these, the majority of emissions (~ 70% of total) were due to traffic moving in and out of the port of Los Angeles-Long Beach. Therefore a shift from road to rail led to an estimation of a total reduction of 1.7 MMT of CO_2.

Despite all these policies and models that have been developed to ensure a modal shift from road to rail, waterways and air, the transition is rather slow and more research is needed to determine the overall opportunities for mode-shifting.

5. RESULTS OF MODELS ANALYSIS

The results from the models that have been reviewed in this paper show that from the structural equation model; subsidy, tax and pricing had positive effects on promoting a modal shift. Hence, subsidy, tax and pricing have an effect on improving services. Travel time and cost also considered as major variables in choosing transfer modes. The results also showed subsidy supports directly the improvement in rail network capability and capacity that reduces travel time. A road haulage tax and road pricing promote the modal shift from road to rail by affecting costs in road freight transport. Hence a drop in travel time and cost attracted customers to change from road to rail. Moreover, services produce positive effects on promoting modal shift. Therefore, the improvement in rail service attracts stakeholders in a supply chain, like freight forwarders and consigners to change the mode from the road to rail. These services produce positive effects on establishing strategic planning and operation which leads to a positive effect on developing infrastructure. Furthermore, services require providing reasonable rail networks and infrastructure through planning and operation and these, in turn, need to build appropriate infrastructure, which attracts freight transportation from road to rail.

While Xuezong Tao's analytical tool model revealed that to achieve a cost-effective modal shift, giving a subsidy of 400RMB/TEU to shippers who use SRIT will be a relatively optimal choice for sea-rail intermodal transport between Ningbo Port and East Jiangxi province.

While using the AHP model and Game Theory models to determine modal shift from inland waterways and coastal shipping to rail, the result of the models showed that modal shift would happen if the ballast water treatment methods are mandated without financial incentives. Hence it is advisable to apply mandatory ballast water treatment requirements for the ships entering the great lake from overseas.

And lastly, the results from the GIFT model showed that significant reductions in CO_2 emissions are possible through intermodal changes and other energy-efficiency measures that would support the Air Resources Board goods movement goals.

The last but the not the list, government policies such as grants, subsidies also play a major role in ensuring modal shift especially in the U.S and among countries in the Euro Zone.

6. CONCLUSION

All the policies and models discussed in this paper shows that the goal to achieve a modal shift from road to the other modes of transport is not far-fetched. Despite the challenges that are faced with the modal shift with respect to reliability, efficiency and effectiveness, more research still has to be carried out to determine the actual opportunities associated with the modal shift.

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