Modeling Inland Intermodal Container Transport Systems in Taiwan

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***Abstract*—**The growth in use of containers and the creation of joint ventures in the shipping industries have all put pressure on seaports. The concept of hinterland is becoming obsolete through the use of containers providing intermodality and reflecting inter-port competition and port concentration. The context of inland container transport originally resulted from the port-hinterland relationship between regional industries and port infrastructure. However, the development of inland container transport has developed in more recent times according to the concept of a hub port with feeder ports. This paper discusses the validity of using the gravity model approach to study inland container transport in the context of the above development. The study assesses the role of distance on the performance of inland container transport and evaluates how that role has changed over time with new transport technologies and logistics systems. The simple gravity model was used to estimate distance elasticity and the time trends for inland container transport for the past 10 years in Taiwan. The results for the aggregate categories were similar to previous research. However, there was statistical evidence of a declining effect of distance when port-hinterland relationship data were used. The paper examines reasons for this declining effect.

***Keywords*—**Containerisation; Gravity Model; Hinterland; Intermodality; Inter-Port Competition; Port Concentration.

***Abbreviations*—**Forty-Foot Equivalent Unit (FEU); Round-The-World Services (RTW); The European Conference of Ministers of Transport (ECMT); Twenty-Foot Equivalent Unit (TEU).

I. INTRODUCTION

SEAPORTS have traditionally been a dependent element of the transportation systems within which they operated, and the rise of intermodal transport has resulted in dramatic changes in the pattern of freight transport and port competition in worldwide shipping. Transport systems have seen both revolution and the evolution, the first revolution was in the ship-to-shore transfer, the invention of container; the second revolution was in the ship-to-rail transfer sometimes called intermodal; and the third was in the ship-to-ship transfer the transhipment. First, containerisation and then intermodality in the late 1970s, also known as multi-modality, have caused a tremendous impact on every facet of the transport system. While containers have greatly improved the intermodal transfer of general cargo, containerisation and intermodality are not synonymous terms, although intermodality is a natural continuation of containerisation. When containerisation becomes a dominant technique in the general cargo trade, the intermodal transport network expands and container traffic further concentrates on a limited number of larger ports or terminals [ECMT, 2001].

There are different schools of thought regarding containerisation and intermodality. The movement of goods in a single container by more than one mode of transport was an important development in the transport industry and for all elements in international and domestic trade. The unitisation in the use of containers as standard equipment, the creation of joint ventures in the shipping industry and the trend to larger container ships have all put pressure on seaports. In international shipping we have to understand three very fundamental concepts; port to port, port to point and point to point. Point to point and origin-to-destination moves imply transportation between the shipper’s door and the customer’s door. The point-point movement is the characteristic of intermodalism. There has been rivalry among ports for traffic to and from hinterland regions, but the concept of hinterland is becoming obsolete through the use of containers providing intermodality. This reflects inter-port competition on an international basis and global trends towards port concentration. As major connecting nodes in national and international transport systems, ports play a very important role in the trade development of a regional economy. Container ports were the important nodal points in the entire global logistic chains of containerised freight transportation [Baird, 2006]. Global trends in containerisation inevitably affect container ports both directly and through changing the environment in which they operate. The new trends affecting the container freight industry are explored mainly by reviewing the recent literature on containerisation [Hess & Rodrigue, 2004; Bae et al., 2013; Casaca et al., 2013] and container port development in different parts of the world [Woodburn, 2001; Barros & Athanassiou, 2004; Song & Yeo, 2004; Notteboom & Rodrigue, 2005; Notteboom & Rodrigue; 2008; Asgari et al., 2013; Castillo-Manzano et al., 2013; Rodrigue et al., 2013]. The port, being an interface of land and sea transport, has been conceptualised as the first and most fundamental anchorage point for colonial powers to control the developing world. It was only at later stages that lateral interconnections and inland nodes were developed [Tan, 2007]. The subject of port geography focus on discussion of the evolution of the intermodal shipping network, port hinterlands, and forelands from this earlier era, and articulated the discrete components of this academic focus. These elements, port, carrier, cargo, hinterland, foreland, and maritime space were defined and emphasised a need for study of ports in the context of relational patterns, rather than as isolated entities. He noted that each port tended to serve its own hinterland, as a port does not necessarily have exclusive claim to any part of its hinterland, and an inland area may be the hinterland of several ports. Initially, ports served their hinterlands and forelands using newly laid railroad tracks. Effective organization and utilization of the land exert a powerful influence both on the evolution of ports and port functions and on the organization of maritime space, and the character and growth of a port play a leading role in the development and prosperity of the hinterland and maritime organization. As a general framework for analysis of ports and their activities, these delineations of the components and subsystems of port geography were a contribution of major importance.

Under the traditional view of the shipping industry, cargo was always shipped from its inland production centre to the nearest port. Carriers normally designed routes to cover all ports within a coastal range. Under these circumstances, ports secured the cargo from their captive hinterlands and port competition was scarce. Ships early in the last century handled cargo in the break-bulk method. General cargo was often packed in burlap sacks or shipped loose or unpackaged, later placed on wooden pallets, and loaded and off-loaded onto other modes of transportation by longshoremen. This was a slow, labour-intensive process that could leave the ship in port for several days. This scenario began to change during the 1960s with the introduction of the container. Containerisation eased cargo handling and reduced loading and unloading times at a vessel's berth. Important innovations on the inland transportation systems arose as well. Containers are reusable, either 20 or 40 feet in length known as TEU (20-foot-equivalent-unit) or FEU (40-foot-equivalent-unit) in the industry. Containerisation was an important technological advancement in shipping.

The containerised system was so successful that more and more large ports began to install new and costly gantry cranes. The gantry cranes are situated on tracks along the container ship berths and are devised especially for rapid container handling at their terminals. The large container ships required not only new shore-side equipment; they also required deeper water for berthing and deeper turnaround channels and harbour entrances. Larger ports that could afford to expand and modernize their facilities began installing gantry cranes for containers and began plans for the deepening of channels. They can be single or double stacked on containerised vessels and are lifted on and off ships, truck beds, or rail cars by large overhead gantry cranes or carried to adjacent container yards by straddle cranes. Cargo in the container does not have to be individually handled or repacked as it moves from the ship to the dock and finally to the truck or train on the way to its final destination. The combination of transportation modes appeared as a competitive alternative to all-water services, and ocean carriers began offering intermodal services at competitive rates. Intermodalism implied a profound change in the organisation of the shipping business. The number of ports through which an individual shipment could be directed increased significantly, and ports began to compete for the intermodal cargo. At the same time, ocean carriers began organizing their fleets to serve primarily the ports where the intermodal cargo would be concentrated. The historical connection between each port and its hinterland has been explained as a result of the regulation of both maritime and inland transportation. The growing progression in the use of standardized containers in maritime transport and the technological revolution associated with this has involved deep changes in the nature of inter-port competition. For example, the concept of the hinterland is becoming obsolete because the use of containers provides intermodality and so removes the monopolistic position of ports in adjacent influencing areas.

Inter-port competition is not focused, however, exclusively in their adjacent area and more and more it has to do with the function of transhipment, which is attracting throughput with origin or destination at another port. Shippers organise container throughput sometimes by means of Round-The-World services (RTW). Their reasoning lies in using huge ships that call in at a few strategic ports where transhipments are carried out from/to ports of origin or destination ports through feeder ships. The broadening of container use has involved deep changes in maritime transport, especially with regard to port competition. Fast, reliable, and relatively cheap transport of goods allows firms to compete efficiently and effectively in markets that have become increasingly internationalised and in which ever higher logistical demands are requested. In practice, shipping firms who generate the demand for freight transport have become less and less sensitive to transport costs: the logistical organisation has become more and more transport-intensive, due to among other factors centralisation of production and elimination of inventories. Minimization of logistical costs other than the cost of transport seems to be of primary importance to shipping firms. This raises the question to what extent transport policies that aim to affect transport costs will prove to be effective in reducing the growth in freight transport [Runhaar, 2002]. Port competition models based on survey disaggregate data at the individual level have been applied in a number of studies [Malchow & Kanafani, 2001], but such models can also be employed with aggregate data using the logit choice model with aggregate origin-destination data to assign traffic between alternative routes. For planners normally working at this level, it is necessary to have estimates of traffic from origins to destinations, which can be made with gravity models. Gravity models of trip distribution became well known during the 1960s and 1970s and continue to be used in many places. A maximum likelihood procedure is usual for estimating the parameters. The gravity equation has been long recognized for its consistent empirical success in explaining many different types of flows, such as migration, commuting, tourism and commodity shipping.

In inland container transport, bilateral gross aggregate container flows are surveyed in Japanese major ports for trip distribution and distance specification. Typically, the log-linear equation specifies that a flow from origin i to destination j can be explained by economic forces at the flow's origin, economic forces at the flow's destination, and economic forces either aiding or resisting the flow's movement from origin to destination. The context of inland container transport has resulted from the port-hinterland relationship between regional industries and port infrastructures. A problem of inland container transport has resulted from the imbalanced flow between origin-destination traffic. In the past ten years, this has been apparent in inter-port competition and the traffic of inland container transport for the three major ports in Taiwan. The problem was caused by insufficient industrial distribution in the south or lack of port capacity in the north. The programme called "Inland Container Transfer by Coastal Shipping" was not carried out between Keelung and Kaohsiung, owing to the cost of road freight transport between the two ports being cheaper than coastal shipping in Taiwan. Because Taiwanese authorities have adopted a transport policy more appropriate for a continental land-map for years, sea transport is weaker than land transport. Furthermore, road freight transport is stronger than rail freight transport, and port development for sea transport is more in the south than in the north of Taiwan, so the road network is well developed. The pattern of container traffic has resulted from the focus of national port planning on port development on Port of Kaohsiung, in the south of Taiwan, and not the Port of Keelung. The Taiwanese government will develop Kaohsiung port to be the "Global Logistics Management Centre", but the source of containers is mainly from the northern area and, since container transport by railway and coastal shipping is not well developed, there are millions of container trailers on the roads each year. The phenomenon of inland container south-north transport makes the roads more crowded and carries a lot of social investment in road maintenance. Therefore, it is the aim to research the extent of inland container traffic for the past ten years in Taiwan in order to investigate traffic flow in terms of container transportation and trip distribution. This is done by using the gravity model in which to set up the inland container transport model in order to assess quantitatively the impact of distance for each port. This paper discusses the validity of using the gravity model approach to study inland container transport in the context of the above development. The simple gravity model was used to estimate distance elasticity and the time trends for inland container transport for the past ten years in Taiwan. There was statistical evidence of a declining effect of distance when port-hinterland relationship data were used. The paper will examine the reasons for this declining effect.

II. METHODS OF DATA COLLECTION

A seaport gateway is a basic import/export door-to-door element of a nation's economy. Port infrastructure is an important part of every country's communication system. In recent decades, seaport operation has been modified dramatically. Important changes in the worldwide trade patterns have resulted from the rapid emergence of new economies. The booming Asian economies and the increasing globalisation of production systems have changed substantially affecting maritime flows, favouring some ports and disfavouring others. Forces of globalisation have increased competition just as trade flows have increased, causing more and more competitors to share part of the economic benefit. The speeds by which goods can be transported across vast areas have therefore made the efficiency of logistical infrastructure a central aspect of economic growth. Since the primary gateways for goods flowing across oceans remain seaports, the efficiency of ports is central to the economic growth and prosperity of regions that extend beyond the ports themselves. However, more important than this geographically evolving cargo distribution has been the profound transformation occurring in the organisation of the shipping business. With the growth of containerisation and the enhancement of the inland transportation system, new capabilities have been opened for intermodal freight transportation. The number of ports through which cargo could be efficiently shipped to or from each inland location has increased significantly. Carriers have gradually increased their influence toward the routing of cargo, selecting ports that better fit their overall scheme. The concept of a port as a unique 'gateway' to its proprietary hinterland has vanished. Ports are now more dependent upon carriers' decisions. Under these circumstances, competition among ports has intensified, particularly among container ports.

Seaports compete in a relatively free market system as carriers are free to choose, within limits imposed by the commodity, shippers and the inland carriers, and their ports of call. Therefore individual ports have to continually upgrade their facilities and services to keep pace with the competition and with changes in the shipping industry. The trends towards larger vessels, containerised shipments, intermodalism, relaxed shipping regulation, shipping alliances and mergers, and service rationalization have all directly impacted on ports. Port competition can exist in two geographical ways: international and domestic. In the international dimension, ports in different countries can compete to handle the same business, because they serve similar hinterlands or can both serve as land bridge access points. Shippers are requesting an improved distribution of their goods as they seek worldwide coverage. Carriers as a result are streamlining their operations while simultaneously broadening their operations' scope and geographical reach. The fact that neighbouring countries can follow differing policies regarding infrastructure planning is extremely salient with regard to the effect such policies will have on affecting trade volume. In the domestic dimension, ports within the same country compete with each other for business. This can occur between ports over great geographic distance, as when they compete with others for cargoes imported/exported to/from the same country; such regions that serve similar hinterlands and/or functions compete for the same cargoes. This port competition can occur domestically or internationally. Major carriers must now offer complete logistical support for the door-to-door movement of freight. Carriers at the same time are facing competition from within, responding to a realignment of the industry. Mergers and alliances between carriers are evolving, pushing the sector toward consolidation. Services offered by carriers are constantly being modified to satisfy efficiency requirements for these alliances. Seaports, as an important part of the maritime network, are being affected. This new competitive environment presents a challenging situation for port managers and public administrators, one in which planning strategies and investment decisions must be evaluated carefully. The demand for seaports comes from shippers and carriers, who choose which ports they will use based on a number of criteria, such as cargo compatibility, access to hinterlands, cost, security, labour productivity, customs, equipment availability, and the presence of foreign trade zones [Kumar, 2001].

There are two key areas of competition including the ability of ports to attract business by seamlessly handling intermodal freight movements and meeting environmental regulations in a cost-efficient and non-burdensome manner. In order to be competitive in today’s market, a port that wishes to be a major load centre must offer these services, and offer them at a price low enough to retain demand for those services. Because port services are so capital-intensive, it is easy to assume that large economies of scale must be necessary to operate competitively, and that economies of scale will only benefit large load centres. However, large load centres also have large costs, and economies of scale may not make up for those sizeable costs. The costs in the shipping industry are a consequence of an unstable market due to loading factors and fuel price. The reduction in the speed of vessels to save on fuel costs will mitigate the effects of a possible down turn in world trade. Port operation will not be directly affected anywhere near as much by the fuel price but the sunk cost of facilities are inescapable. Either the large costs have to be made up for by some other method, or small ports can take advantage of some of the inefficiencies of larger ports. It should be noted that competition between ports is far from perfect in an economic sense. There are barriers to entry, such as the intense capital requirements just mentioned, and there are some ports that enjoy highly monopolistic situations, and therefore face little competition. These factors limit the speed and effectiveness of competitive marketplace forces, producing, in effect, inelastic supply, at least in the short term. Over the long term, this supply becomes more elastic as ports can eventually adjust their ability to compete. Competition can be more intense between ports that already have made the necessary capital investments in shore-side facilities and that serve similar trades and have overlapping hinterlands. Within the range of ports stretching from Le Havre to Hamburg, for instance, there is a string of ports of various sizes serving similar trades and offering overlapping hinterlands. In North America, Seattle and Tacoma are known to compete for the same business, offering similar services and essentially identical hinterlands. However, no two ports are identical and each port offers its own unique mix of services and assets. This means that competition between ports occurs not on the basis of price alone, but on the basis of a port’s complete offerings. Even small ports find that they can meet a certain market niche better than others do and survive on that basis. Since 1980, Taiwan has had an inland container flow problem, resulting from a rapid growth in flow volume from 510 thousand TEUs in 1990 to 1137 thousand TEUs in 2010. The inland container flow ratio in Taiwan was given in table 1, also with the key locations was shown in figure 1. The phenomenon of inland container flow will be divided into three kinds of container flow: northern to central or southern, central to southern or northern, and southern to central or northern. The inland container flow volume from northern to central or southern was 614 thousand TEUs in 2010, flow volume from central to southern or northern was 392 thousand TEUs in 2010, and flow volume from southern to central or northern was 131 thousand TEUs in 2010.

Table 1: The 2010 Inland Container Transport Volume in Taiwan (Unit: TEUs)

	Taichung To Keelung	Kaohsiung To Keelung	Keelung To Taichung	Kaohsiung To Taichung	Keelung To Kaohsiung	Taichung To Kaohsiung
Inbound	33,556	240,066	12,438	115,161	14,196	4,846
	Keelung To Taichung	Keelung To Kaohsiung	Taichung To Keelung	Taichung To Kaohsiung	Kaohsiung To Keelung	Kaohsiung To Taichung
Outbound	67,491	273,354	32,373	232,420	59,860	52,128
Total	1,137,889 (2010)					

(*Source*: The Department of Statistics Ministry of Communications, Taiwan, 2012.)

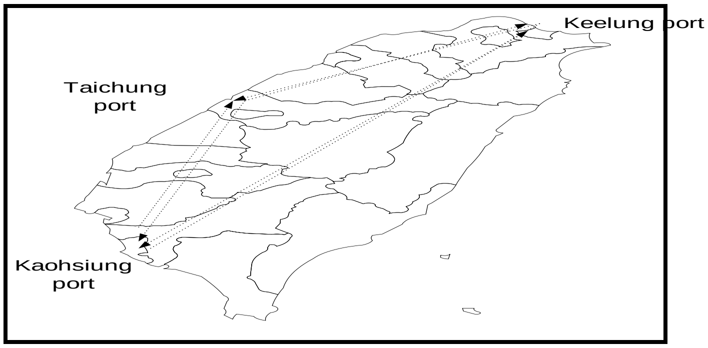

Figure 1: Inland Container Transportation Access of Major Ports in Taiwan

Based on the annual reports of the Taiwanese Ministry of Transportation from 1990-2010, statistics indicates the haul distance of the inland container transportation between the three major container ports of Taiwan were shown in table 2.

Table 2: The Average Inland Container Haul Distance for Major Ports in Taiwan

Year / Port	1990	2000	2010
Kaohsiung	179.2 Km	143.0 Km	163.6 Km
Taichung	70.0 Km	53.1 Km	78.4Km
Keelung	57.0 Km	48.2 Km	87.5 Km

(*Source*: The Department of Statistics Ministry of Communications, Taiwan, 2012.)

The customs statistical data provide the inland container transport volume ratio for exports and imports of each port in Taiwan, estimated from 1990 to 2010. Import potential container volume is 56.3% in Keelung port, 8.0% in Taichung port, and 35.7% in Kaohsiung port. Export potential volume is 60.5% in Keelung port, 14.8% in Taichung port, and 24.7% in Kaohsiung port. Therefore, Keelung port has the largest percentage of the potential container volume of the three ports. Basically, Keelung port serves the northern region that is the main source of container cargoes, containing about 60% of all the volume in Taiwan. Furthermore, as the potential volume of Taichung port increases, Keelung port and Kaohsiung port decreases year by year. Taichung port is increasing the source of container cargo in the central area, and sharing part of the container cargo volume through Keelung port. Kaohsiung port has decreasing volume access from Keelung port and Taichung port due to container ship berthing in one single hub port. Also based on the report of "Cargo Transport Investigation in Taiwan Area", the trip length of inland containers between each port and zone is equivalent to the service area of each port shown in table 3.

Table 3: Average Trip Length of Inland Container in Taiwan

Year / Port Zone	2000	2005	2010
Keelung	53.2Km	57.0Km	48.2Km
Taichung	99.7Km	70.0Km	53.1Km
Kaohsiung	169.8Km	179.0Km	143.0Km

(*Source*: The Department of Statistics Ministry of Communications, Taiwan, 2012.)

III. Results of the Survey Analysis

The model of inland container through transport suitable for Taiwan is established on the basis of the theory of the gravity model. Its elements include the quantity of the flow among counties, cities and ports, the container volume among counties and cities, the load and unload volume of each port, the average of the transport distance among counties, cities and ports; the load and unload expense on shore and the average time of waiting for ship space to make a comparison. This model considers the county-city–port through transport volume, the county-city container volume the load and unload volume of the port and the average transport distance of the counties and ports. The basic formula is as follows:

$$F_{ij} = c\frac{P_i^{\alpha} \times Q_j^{\beta}}{D_{ij}^{\gamma}} \quad (1)$$

Where

F_{ij}: was the load and unload container volume form zone i to port j

P_i: was the container volume of productive form zone i

Q_j: was the container volume of attractive to port j

D_{ij}: was the distance form zone i to port j

C : was a constant

α, β, γ were parameters

Equation (1) is transformed into the logarithm regression equation to form equation (2), the regression formula with logarithm as follows:

$$lnF_{ij} = ln\ C + \alpha lnP_i + \beta lnQ_j - \gamma lnD_{ij} \quad (2)$$

Adding the reference value to equation (1) the port gravity model was shown in table 4 as follows:

(1) Keelung Port:

$$F_{ij} = 9.849 \times 10^{-4} \times \frac{P_i^{1.424} \times Q_j^{1.250}}{D_{ij}^{-2.915}} \quad (3)$$

(2) Taichung Port:

$$F_{ij} = 1.190 \times 10^{-3} \times \frac{P_i^{1.455} \times Q_j^{1.149}}{D_{ij}^{-1.932}} \quad (4)$$

(3) Kaohsiung Port:

$$F_{ij} = 0.065 \times \frac{P_i^{0.981} \times Q_j^{1.617}}{D_{ij}^{-1.361}} \quad (5)$$

Table 4: The Results of the Inland Container Traffic Gravity Model

Items	Keelung Port	Taichung Port	Kaohsiung Port
R^2	0.794	0.738	0.766
The constant (C)	$9.849*10^{-4}$	$1.190*10^{-3}$	0.065
The parameter of productive volume form zone i (α)	$1.424^*(3.3*10^{-5})$	$1.455^*(1.8*10^{-9})$	$0.981^*(7.4*10^{-17})$
The parameter of attractive volume to port j (β)	1.250	1.149	1.617
The parameter of distance(γ)	$-2.915^*(5.2*10^{-5})$	$-1.932^*(1.0*10^{-5})$	$-1.361^*(2.7*10^{-11})$

Note: the value inside ( ) is p-value

Some findings from the results of the gravity model of inland container traffic as follows:

1. The R^2 value above 0.7 assumes container traffic flow is reasonable.
2. The value of parameter of volume attracted to port j as (β) can explain the situation of load and unload volume. That is to say the priority is Kaohsiung Port (1.617), Keelung Port (1.25) and Taichung Port (1.149).
3. According to the value (γ) of distance D_{ij}, the distance has the greatest impact on the containers traffic through Keelung Port; it has the smallest effect for container traffic through Kaohsiung Port.

IV. CONCLUSIONS

The paper discusses the inland container traffic, the analysis of the container trip distance and the spread of container resources, and constructs a model of the inland container transport, which uses the gravity model to study the characteristics of the inland container traffic. Since the 1980s, the problem of Taiwan's inland container transport is increasingly serious; the traffic volume has increased from about 260,000 TEUs in 1990 up to about 922,000 TEUs in 2010. The resources of container traffic flow in Taiwan concentred mostly in the northern area with about sixty percent of the total container import and export cargo; the middle area is about fifteen percent, and the southern area is about twenty-five percent [Asgari et al., 2013]. The hinterland range of Keelung port is clear-cut; the hinterland range of Kaohsiung port is less so; the hinterland range of Taichung port has become increasingly obvious in the recent two or three years. Two issues are worth further consideration. Firstly, the element of waiting time and port expense for ship berths, the carrier would select to call at Kaohsiung port rather than Keelung port as a hub port. And then applying transportation technology for Post-Panamax container ships to berth at Kaohsiung port for complete intermodal transport systems is less expensive than other ports.

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