MODELING THE OPTIMAL MODE SPLIT FOR FREIGHT TRANSPORTATION IN TAIWAN AREA --FROM THE VIEWPOINT OF MODAL SHIFT

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Abstract: In the recent twenty years, the inland container transport flow in Taiwan area increases from 260 thousand boxes in 1983 to 922 thousand boxes in 1997. Such a large amount has caused the impact on traffic flow, energy, environment, labor and so on. Therefore, it is worth to do a research on how to transfer highway transport to railway or ship transport for mitigating the inland container transport flow. This study we use the gravity model to set up the inland container through transport competitive model to find the factors of the inland container transport flow in Taiwan area. From the viewpoint of modal shift model, we combines loading/unloading operation and transport method to establish the total cost function of the three transport methods, to set up an index, and chooses transport method based on the criteria of minimization cost.

Key Words: Inland Container Transport, Competitive Model, Modal Shift

1. INTRODUCTION

Taiwan is an island, but the authorities have focused on land transport policy for years, therefore, sea transport is weaker than land transport. In land transport, the highway transport is emphasized more than railway transport in cargo transport, and government has paid much more efforts on the port development for ship transport in the southern than that in the northern, so the highway net is well developed. In addition, for the national income increases, so there are lots of automobiles, and the highway reaches the limit of its designed capacity earlier than expected. As to container transportation of Taiwan area, owing to

(1) Here is an over-emphasis on the development of Kaohsiung Port, in the southern Taiwan,

(2) There existing lots of difference of the expenses for container berthing in the different ports because of the different charging system between Kaohsiung Port, which wharves are for rent, and Keelung Port, which wharves are for public,

(3) Vessels becoming larger than before, ship companies prefer to moor the container mother ships in Kaohsiung Port, rather than Keelung Port.

In addition, recently government has been developing the Kaohsiung Port to be "Asia-Pacific Transshipment Center", but the source of containers is mainly from the northern area (about 60%) and the container transportation on railway or by ships is not developed, so there are 800,000 trailers on the freeway each year. This makes the freeway more crowded and people should share a lot of expenditures on road maintenance, traffic accident, energy consumption and environmental destruction. Therefore, it is the aim to research the feasibility of transferring highway transport to ship or railway transport in order to deduct the inland traffic flow of containers.

This paper specifies in Keelung port, Taichung port and Kaohsiung port, and the purposes are listed as following:

(1) The source and distribution ratio of the containers for each zone depending on container through transport situation. According to the distribution of the inland container through transport, we'll use the gravity model to build up the inland container transport competitive model of each port by considering the following factors: (a) the loading and unloading capacity between each port and each area, (b). the source of container of each area,(c) the distance gap between each port and each area, (d) the waiting time for ships in each port and (e)the loading and unloading cost for each port.

(2) Analyzing container operation system, then combining different transportation method to establish a model and some judged index of container transport of Taiwan area. Then we can realize the competitive distance relation and effect degree of each variable among this three-transport method, and we try to provide policy-makers that the factors they should consider while transferring highway transport to railway or ship transport. Finally, we hope to find out the solution of inland container transport of Taiwan.

2. INLAND CONTAINER TRANSPORT ANALYSIS

Before going on the next analysis of this subject, we define the following term:

A. Potential Demand: In container through transport analysis for the revise operation volume from each port, called the potential demand of transport volume of each port. Basically, the volume is the minimum distribution volume from port to each zone, that the volume has the connection relationship with port service area.

B. Operative Demand: The volume from government statistics, actual operation volume of each port.

C. Inland Container Transport: Those sources of container in the northern area not export from Keelung port but transship to Taichung port or Kaohsiung port, and import from above two port to transship to northern area.

2.1 Inland Container Through Transport Growth Analysis

Since 1980, the Taiwan area has the inland container through transport problem, the through transport volume grow rapidly, the volume is 260 thousand boxes in 1983, and 1138 thousand boxes in 1999.Here is the statistic of the inland container through transport ratio for full container in Taiwan area (shown in the Table 1.), the ratio is 24% in 1983 and 30% in 1999.

Table 1. The Recent 15 years through transport volume in Taiwan (unit:box)

flow\ year	1983	1985	1987	1989	1991	1993	1995	1997
Keelung→ Taichung	706	4242	10353	14916	10073	8743	14707	45002
Keelung→ Kaohsiung	156200	129356	164022	216680	184854	229824	232205	297294
Taichung→ Keelung	14888	25169	46956	51407	52839	41002	49512	61149
Taichung→ Kaohsiung	20248	35612	52901	69714	103175	152092	152167	157026
Kaohsiung→ Keelung	59798	68373	89817	131585	119955	179186	284316	234827
Kaohsiung→ Taichung	3904	9481	27190	40561	86491	74802	123528	114423
through transport volume (A)	255744	272233	391239	524863	557387	685649	856435	909721
the number of export and import container (B)	1063186	1183060	1799481	1999165	2331666	2563131	2830121	3043658
Ratio(A/B)	**24.1%**	**23.0%**	**21.7%**	**26.3%**	**23.9%**	**26.8%**	**30.3%**	**29.9%**

Source：The Discussion of the Current State of Taiwan Container Management, 1997

The types of inland container through transport will be classified to three kind of container through transport: (1) northern to central or southern, (2) central to southern or northern and (3)southern to central or northern. The inland container through transport volume from northern to central or southern is 184 thousand boxes in 1983, and 498 thousand boxes in 1997.Through transport volume from central to southern or northern are 39 thousand boxes in 1983,and 305 thousand boxes in 1997. Through transport volume from southern to central or northern is 330 thousand boxes in 1983 and 107 thousand boxes in 1997.

2.2 Distribution Analysis for Source of Container Cargo in Taiwan

According to the custom statistics, the inland container transport volume ratio for export and import of each port in Taiwan is estimated from 1971 to 1996.(shown in Table 2.)

The following data display for export and import container transport volume ratio in each port: Import potential volume is 57.7% in Keelung port,14.5% in Taichung port and 27.8% in Kaohsiung port. Export potential volume is 51.4% in Keelung port, 24.6% in Taichung port, and 24.3% in Kaohsiung port. Therefore Keelung port has the largest percentage of the potential container is the main source of container cargo, representing about 60% of the all volume in Taiwan area.

Besides, the potential volume of Taichung port increases, and Keelung port and Kaohsiung port decreases year by year. As the Taichung port was a trend of increasing sharing container cargoes from Keelung port. For Kaohsiung port, the volume of container cargo from Keelung port and Taichung port is in the trend of decreasing.

Table 2. the recent 20 years Operation & Potential Volume Ratio in Taiwan (%)

Year	Operation Volume						Potential Volume					
	Keelung Port		Taichung Port		Kaohsiung Port		Keelung Port		Taichung Port		Kaohsiung Port	
	Import	Export	Import	Export	Import	Export	Import	Export	Import	Export	Import	Export
1977	44.6	50.5	0.3	0.5	55.1	49.0	44.6	50.5	0.3	0.5	55.1	49.0
1978	42.5	48.1	0.1	0.3	57.3	51.6	42.5	48.1	0.1	0.3	57.3	51.6
1979	47.5	47.1	0.0	0.5	52.5	52.4	47.5	47.1	0.0	0.5	52.5	52.4
1980	46.8	47.2	0.0	0.5	53.2	52.3	46.8	47.2	0.0	0.5	53.2	52.3
1981	41.5	44.7	0.0	0.6	58.5	54.6	41.5	44.7	0.0	0.6	58.5	54.6
1982	45.4	46.8	0.1	0.5	54.5	52.6	53.7	61.2	1.2	3.2	45.1	35.6
1983	45.4	52.9	0.3	0.5	54.3	46.6	52.9	68.6	1.3	5.4	45.8	26.0
1984	37.4	58.9	0.1	0.5	62.5	40.6	43.1	66.2	1.9	5.1	55.0	28.7
1985	46.2	56.4	0.3	1.1	53.5	42.6	53.4	64.9	3.8	8.7	42.8	26.4
1986	47.9	55.2	0.9	1.8	51.2	43.0	53.5	64.4	7.2	10.5	39.3	25.1
1987	50.5	54.1	1.1	2.0	48.5	43.9	55.2	59.8	7.2	10.6	37.6	29.6
1988	50.7	52.5	1.8	4.0	47.5	43.5	57.4	57.9	7.5	12.6	35.1	29.5
1989	53.8	53.6	1.9	4.6	44.3	41.9	59.3	61.4	8.7	14.7	32.0	23.9
1990	52.2	58.0	2.5	4.6	45.2	37.3	58.8	65.4	9.6	15.2	31.6	19.5
1991	47.9	53.0	3.0	7.1	49.1	39.9	54.7	57.8	10.6	18.4	34.7	23.8
1992	51.2	50.8	3.7	10.6	45.1	38.6	61.0	57.6	10.7	22.5	28.3	19.8
1993	51.1	51.6	4.3	11.0	44.5	37.4	62.8	60.9	12.1	23.7	25.1	15.4
1994	50.6	49.8	5.3	12.2	44.1	38.0	62.4	58.7	12.8	25.8	24.9	15.6
1995	49.1	49.5	5.6	13.0	45.3	37.5	59.4	51.4	11.3	20.7	29.3	27.9
1996	46.5	43.0	7.6	15.1	45.9	41.9	56.7	50.9	14.3	25.5	29.0	23.5
1997	41.4	39.5	10.1	19.5	48.5	41.0	54.1	50.7	17.2	27.5	28.7	21.8
1998	39.6	29.7	13.7	17.7	46.7	52.6	55.3	42.5	18.7	24.8	26.0	32.7
1999	34.9	25.1	14.3	18.5	50.7	56.4	50.1	38.7	18.9	26.4	31.0	34.9
8Year average	45.5	42.4	8.1	14.7	46.4	42.9	57.7	51.4	14.5	24.6	27.8	24.3

Source：Chen, (1998) and Huang, *et al*(1995)

3. MODELING THE INLAND CONTAINER THROUGH TRANSPORT SYSTEM

According to Watanabe Y.(1998), the model of the inland container through transport suitable for Taiwan is established on the basis of the theory of the gravity and then the model is discussed with two stages on the basis of the 1994 data. On the container through transport model established in the first stage, we have considered the following elements : 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. Then in the second stage we add the load and unload expense on shore and the average time of waiting for ship space to make a comparison.

3.1 The inland container through transport gravity model

The stage just 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 formula is as follow:

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

where

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

P_i: the container volume of productive form zone i

Q_j: the container volume of attractive to port j

D_{ij} : the distance form zone i to port j
C : a constant and α 、β 、γ are parameters

Transferring the equation (1) into the liner regression formula with logarithm as follows, and then adding the former information to the equation (2) as follows :

Table 3 The result of the through transport 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 parameters 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 parameters of attractive volume to port j (β)	1.250	1.149	1.617
The parameters 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

$$\ln F_{ij} = \ln C + \alpha \ln P_i + \beta \ln Q_j - \gamma \ln D_{ij} \tag{2}$$

Adding the reference value to the equation (1) so the port gravity model is showed as follows :

(1) Keelung Port:

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

(2)Taichung Port:

$$F_{ij} = 0.065 \times \frac{P_i^{0.981} \times Q_j^{1.617}}{D_{ij}^{1.361}} \tag{4}$$

(3)Kaohsiung Port:

$$F_{ij} = 1.190 \times 10^{-3} \times \frac{P_i^{1.455} \times Q_j^{1.149}}{D_{ij}^{1.932}} \tag{5}$$

There are some characteristics form the result of the gravity model (shown in Table 3) as follows:

1.The R^2 value above 0.7 and the ability of element explanation is acceptable.
2.The cognitive and negative signal of α , β and γ are coincident with experiences knowledge.
3.The value , β, of the load and unload volume can respond to the load and unload volume . That is to say the priority is Kaohsiung Port (1.617), Keelung Port (1.25) and Taichung Port (1.149).
4.According to the value γ of distance, the distance has the greatest effect on the containers through Keelung Port; it has the smallest effect on those through Kaohsiung Port.

3.2 The Inland Container through transport Competitive Model

As mentioned above, besides the elements of the first stage, in the second stage we add the load and unload expense (R_j) and the average waiting time of ship space to understand the change of the container through transport volume. The model of competition is showed as follows:

$$F_{ij} = c\frac{P_i^{\alpha}}{D_{ij}^{\gamma}}\left(\frac{Q_j^{\beta}}{R_j^{\delta} \times T_j^{\theta}}\right) \tag{6}$$

Transferring the equation (6) into linear regression formula with logarithm, and then adding the former information to the equation (7) as follows:

$$\ln F_{ij} = \ln C + \alpha \ln P_i + \beta \ln Q_j - \gamma \ln D_{ij} - \delta \ln R_j - \theta \ln T_j \tag{7}$$

The reference value is added to the equation (6), so the competition model of ports is showed as follows :

(1) Keelung Port:

$$F_{ij} = 174.784 \times \frac{P_i^{1.424}}{D_{ij}^{2.915}}\left(\frac{Q_j^{1.890}}{R_j^{3.292} * T_j^{3.898}}\right) \tag{8}$$

(2) Taichung Port:

$$F_{ij} = 0.0364 \times \frac{P_i^{1.455}}{D_{ij}^{1.932}}\left(\frac{Q_j^{0.830}}{R_j^{0.587} \times T_j^{1.043}}\right) \tag{9}$$

(3) Kaohsiung Port:

$$F_{ij} = 30.321 \times \frac{P_i^{0.981}}{D_{ij}^{1.361}}\left(\frac{Q_j^{3.087}}{R_j^{3.615} \times T_j^{5.702}}\right) \tag{10}$$

According to the result of the competitive models (shown in Table3), there are some characteristic as follows:

1. The R^2 value above 0.7 and the ability of element explanation is acceptable.
2. The cognitive and negative signal of α, β and γ are coincident with our experiences and common sense.
3. The relevance between each port and reference.

Table 4. The result of the through transport competitive model

Item \ Port	Keelung Port	Taichung Port	Kaohsiung Port
R^2	0.794	0.738	0.766
the constant (C)	174.784	0.0364	30.321
The parameters of productive volume form zone i (α)	1.424*(9.4*10-5)	1.455*(1.5*10-8)	0.981*(4.0*10-15)
The parameters of attractive volume to port j (β)	1.890	0.830	3.087
The parameters of distance(γ)	-2.915*(1.4*10-5)	-1.932*(3.3*10-4)	-1.361*(1.4*10-10)
The parameters of load and unload expense on shore (δ)	-3.292	-0.587	-3.615
The parameters of average waiting time(θ)	-3.989	-1.043	-4.203

Note: the value inside ( ) is p-value.

(1) Keelung Port

a)As for α and β, $\beta>\alpha$,it is due to (6) the through transport distance of Keelung Port is the shortest , most containers transport through Keelung Port except some northern containers through middle-south transportation ; (7) the effect of transferring containers.

b)As for γ, δ and θ, $|\theta|>|\delta|>|\gamma|$, (6) A lot of sources of cargo are in the north of Taiwan ,the port has become more crowded ,and the lower working efficiency makes the time of ship waiting for space longer. That has the most effect. (7) .The load and unload expense on shore has less effect than the waiting time for ship space because of the public wharf. (8) Because most cargo sources spread within the hinterland, the through transport distance has the lest effect.

(2) Taichung Port

a) As for α and β, $\alpha>\beta$,it is because of the longer through transport distance ,part of containers in the middle area transports the south or the north and there are no transferring containers.

b) As for γ, δ and θ, $|\gamma|>|\theta|>|\delta|$, (6)the longer through transport distance has the most effect. (2)due to the tide , the less cargoes and voyages ,the port is less crowd so that the waiting time has limited effect. (8)the load and unload expense on shore is lower than this of Keelung port. because here is the public wharf ,but it has only a limited effect .

(3) Kaohsiung Port

a) As for α and β, $\alpha>\beta$, due to (6)the longest through transport distance. (7)part of northern and middle containers through south transportation and (8) a lot of transferring containers .This part mostly corresponds to table 4.(the quantity of business exceed the quantity of the potential)

b) As for γ, δ and θ, $|\theta|>|\delta|>|\gamma|$,the load and unload expense on shore and the waiting time for ship space have more effect because most ports are for rent so that the businessmen and the owners of cargo mostly use Kaohsiung port because of the lower expense and the shorter waiting time. And here the through transport distance has the effect lest.

4. The relevance of reference among ports

(1) The reference value of the load and unload volume can respond to the load and unload volume of table 7,that is to say that the priority is Kaohsiung port (3.087) ,Keelung port (1.890) and Taichung port.

(2) According to the value γ of distance , the distance has the greatest effect on the containers through Keelung Port ; it has the smallest effect on those through Kaohsiung Port .

(3) The priority of the reference δ and θ of the load and unload expense on shore (Rj) and the average waiting time is Kaohsiung port,Keelung port and Taichung port. This shows that Kaohsiung port with most rented port make the low load-unload expense, short waiting time for ship space and high efficiency possible so that the owners of containers transport through Kaohsiung port resulting to the increase of the load-unload volume.

3.3 The comparison of two models

The β values in the gravity model among ports have little difference(shown in Table 5).

Otherwise, those in the competition model have obvious difference. The major reason is that in the competition model two elements (the load-unload-expense on shore and the average waiting time for ship space) make the difference of the β significant .It shows that the load-unload volume has close relation with the load-unload expense on shore and the average waiting time for ship space.

Table 5. the comparison with two-model of β values among three ports.

Model \ port	Keelung port	Taichung port	Kaohsiung port
The parameters of the β values (gravity model)	1.250	1.149	1.617
The parameters of the β values (competition model)	1.890	0.830	3.087

The gravity model among the spreading model of the transport need of the total procedure is used very widely, especially used for the land transport. The paper referring to the Japanese situation tries to apply to the inland container through transport of Taiwan port transportation on the basis of the gravity model.

Traditionally, the gravity model just considers the relevance of the transport volume between the start and the end, the producing volume, the absorbable volume and the distance. The paper adds the elements of port capacities and the load-unload expense to the second stage. Therefore, the model is also regarded as "the port competition model" from the overall viewpoint of the port design.

The main purpose of this model lists as following:

(1) With the element of waiting time for ship space, the insufficient capacity of Keelung Port and the container source mostly from the north of Taiwan make the waiting time longer so that the businessmen would rather berth at Kaohsiung port with self-rent container port.

(2) With the element of the load-unload expense, the priority ship to berth at Keelung port has to pay the expense of the priority berthing because the Keelung container port is public; and the rent system of Kaohsiung container port makes the load-unload expense lower.

(3) Reflecting the relevance of mutual effect on the elements of the waiting time and the load-unload expense.

4. ESTABLISHMENT OF TRANSPORT METHOD ALTERNATIVE MODEL AND COST FUNCTION

We combined container loading and unloading operation system and transport method to establish alternative models for the reference of shipping companies and port planning personnel as engaging in container loading, unloading and transport. This study takes the transportation process of import from Kaohslung Port tc the north Taiwan as example to establish three transport models.

1.Highway transport method：gantry crane＋loading and unloading alongside vessel＋highway trailer transport

2.Railway transport method：gantry crane＋trailer transport within container yard＋transtainer＋container yard＋straddle carrier＋railway transport＋machine assemble and disassemble＋highway trailer transport

3.Ship transport method：gantry crane＋trailer transport within container yard＋transtainer＋container yard＋transtainer or straddle carrier＋trailer transport within container yard＋

gantry crane + ship transport + gantry crane + loading and unloading alongside vessel + highway trailer transport

And the expenditure of each model is as follows:

(1) .Rent of Dockage (RDK)

RDK is the ratio of unit vessel mooring cost, UDK, and vessel waiting cost of each unit hour, U_S. Based on the container vessel of 10,000~20,000 tons mooring cost daily, UDK, is 756 dollars, and U_S is 17500 dollars (Reference 5). RDK= (UDK/ Us) = 0.0432.

(2) .Rent of Handling Container (RHC)

RHC is the ratio of unit container of 20 foots' handling cost, UHC, and vessel waiting cost of each unit hour, U_S As each container handling cost, UHC, is 1262 dollars, and U_S is 17500 dollars. RHC= (UHC/ Us) =0.072114

(3) .Rent of Wharf Passing (RWP)

RWP is the ratio of wharf passing cost, RWP, and vessel waiting cost of each unit hour, U_S. As wharf-passing cost of 20 foots' container, UWP, is 355 dollars, and U_S is 17500 dollars. RWP= (UWP/ Us) = 0.0040571

(4) .Rent of Storage and Treatment (RST)

RST is the ratio of storage and treatment cost, UST, and vessel waiting cost of each unit hour, U_S. As storage and treatment cost of 20 foots' container, UST, is 260 dollars, and U_S is 17500 dollars. RST= (UST/ Us) = 0.017714

(5) .Rent of Inside Trailer (RIT)

RIT is the ratio of inside trailer cost of Kaohsiung Port, UIT, and vessel waiting cost of each unit hour, U_S. As UIT is 274 dollars, and U_S is 17500 dollars. RIT= (UIT/ Us) = 0.015657

(6) .Rent of Stacking Yard (RYD)

According to the regulation of "Fee Table of International Ports' Business of Taiwan Province", For a 20-foot container UYD is 59 dollars each time daily. RYD= (UYD/ Us) =0.00014

(7) .Rent of Machine (RMi)

UM1, UM2, and UM3 are complied with regulation of "Fee Table of International Ports' Business of Taiwan Province". Using gantry crane for one container each time is 440 dollars and using inside trailer is 274 dollars, and using transtainer or straddle carrier is 391 dollars. U_S is 17500 dollars. RMI= (UMI/ Us) =0.0241, Vice-versa：RM2= 0.016 RM3= 0.022

(8) .Rent of Highway Infrastructure, Rent of Railway Infrastructure, Rent of Ship Infrastructure(RIH、RIR、RIS)

The highway transport cost between Keelung and Kaohsiung at current price is around 8500 dollars. As railway transport cost, it is calculated as 7500 dollars, including business tax of 5%, 5376 dollars of transport cost of 20 foots' container not more than 17.5 tons from Kaohsiung Port to Qidu and 238 dollars of extra container handling cost. And the transport distance (L) of highway and railway is 380km and 420km, and ship transport distance between Keelung and Kaohsiung is 229 nautical mile, about 430km. Therefore, RIH is 0.0012782, and RIR is 0.0010204, and RIS is 0.0003322. Besides, calculating the ratio of DL1 = (420-380) / 380 = 0.1053, DL2 = (430-380) / 380 = 0.1316

(9) .Cost of Inland Transportation (RHY)

The basic cost of land transport of container is 1200 dollars calculated by the distance within 12km. RHY is the ratio of UHY and U_S, vessel waiting cost of each unit hour. RHY= (UHY/ Us) = 0.005714.Owing to that railway and ship transport is unable to complete door to door transport, their distance during land transport, LR and LS, also have to be taken into account. LR : Service scope of container land distribution station which near railway is assumed as 15km. LS : The service scope which using ship transport is assumed as 50km.

(10) .Rent of Time (RTM)

UTM is calculated by 4 times of goods value according to theory of stored cargo. Port parameter is 0.5 (Rcg is the interests cost of loaded cargo). It is assumed as mother ship's capacity is 1177TEU and rate of loading and unloading is 60%. RTM=4* (0.5/1177) =0.002832.

HR : Needed stacking time in container yard by railway transport method

HS : Needed stacking time in container yard by ship transport method (thta is, time of cargo waiting for ship)

TR : Extra time which railway transport taking more than highway transport taking

TS : Extra time which ship transport taking more than highway transport taking

Now, there are eight schedules train for container each day, and this study is to assume that time waiting for train (HR) is 6 hours. Time waiting for ship (HS) is not fixed but we assumed it as 8 hours. As to the time transporting between Keelung and Kaohsiung, it is 6~8 hours during non-rush hour and 8~11 hour during rush hour by trailer on highway, so in this study we take it as 8 hours. And ship transport needs 0.5 hour for loading and unloading and 15 hours for sea transport, so in this study we take it as 16 hours. Additionally the average loading time of railway transport is 10 hours (including loading and unloading time). Therefore, the variables of the time consuming by railway and ship transport exceeding the time by highway transport, according to the definition of TR and TS, are calculated: TR = (10-8) / 380 = 0.0053, TS = (16-8) / 380 = 0.0210

(11) .Waiting cost of trailer (RTK)

UTK is calculated according to the trailer's daily cost (1315 dollars) and the rack cost (274 dollars) and driver should be paid 50000 dollars each month. RTK= (UTK/ Us) = 0.00775

T1 is the time due to trailer's delay by highway transport, assumed to be 1 hour, and T3 is the time due to trailer's delay by ship transport, assumed to be 2 hours.

(12) .Production of Cost (PCi)

PC_1 : Increase of container mother ship's total port cost due to trailer's delay. IF the mother ship's capacity is 1177 TEU ,and we assuming the volume of containers is 1/3 of mother ship's capacity, the ratio of vessel capital each hour of each 20- foot container on the mother ship over U_S, RS1, is 1. PC_1= (Rs1 + Rpf+ Rbf+ Rpo+ Rbo+ Rcm+ Rco) /1177*(1/3)= 0.00828.

PC_2: Increase of container ship's total port cost due to trailer's delay. IF the ship's capacity is 590TEU and we assuming the volume of containers is 50% of mother ship's capacity and each hour's capital of vessel is 7317 dollars. The ratio of vessel capital each hour of each container of 20 foots on the ship and U_S, RS2, is 7317/17500, that is, 0.418. PC_2= (Rs2 + Rpf+ Rbf+ Rpo+ Rbo+ Rcm+ Rco) / 590*0.5=0.00565

Table 6 .Values of Rpf、Rpo、Rbf、Rbo、Rcm、Rco

Rpf	0.75	Rbf	0.25	Rcm	0.1
Rpo	0.1125	Rbo	0.0375	Rco	0.1

Before setting up function of total costs, making the following basic assumptions first:

1.Under the situation before privatization of port operation in each port.
2.There are berths specialized in Port of Kaohsiung, if container mother ship moors on specialized port, then it is calculated by discount of 70% of original price about machine using cost, rent of place and so on (only calculate sharing expense of the rent). Wharf passing-fee and containers handling-cost are not included.
3.The berths in Port of Keelung belong to the public, and the ship transport cots is calculated according to the preferential price rate of transshipment container made by the Ministry of Communications and Transportation: (1)20% discount of container handling cost (2)30% discount of machine using cost (3)50% discount of wharf passing cost (4)50% discount of rent of place.
4.Adopting "Loading and Unloading Alongside Vessel Method" after vessel moors into the berth.
5.The operation of container mother ship and its ship is proceeded within the same container base.

The total costs function of each transport method alternative model is as the following:

1.Highway Transport Method

TC1 = RST + 0.3RM1 + T1*(RTK + RTM + PC1) + RIH*L

2.Railway Transport Method

TC2=RST+0.3(RM1+RM2)+0.3RYD*HR+RTM*HR+0.3RM3+RIR*L*(1+DL1)+RM3+RTM*TR*L+RHY+RIH*(LR-12)
=RST+0.3(RM1+RM2+RM3)+0.3RYD*HR+RTM*(HR+TR×L)+RIR*L*(1+DL1)+RM3+RHY+RIH*(LR-12)

3.Ship Transport Method

TC3=RST+0.3(RM1+RM2+RM3)+0.3RYD*HS+RTM*HS+0.3RM3+0.3RIT+RST+0.3RM1+RIS*L*(1+DL2)+RTM*TS*L+RDK*6+0.8RHC+0.5RWP+0.5RM1+RST+T3*RTK+T3*RTM+T3*PC2+RHY+RIH*(LS-12)
=3RST+1.3RM1+0.3RM2+0.6RM3+0.3RYD*HS+RTM(HS+TS*L)+0.3RIT+RIS*L*(1+DL2)+RDK*6+0.8RHC+0.5RWP+T3(RTK+RTM+PC2)+RHY+RIH*(LS-12)

5.CHOOSING OF TRANSPORT METHOD AND DETERMINATION OF VARIABLE'S EFFECT DEGREE

After establishment of alternative model for transport method, We go on making a decision to choose the suitable method from alternatives, here are the process:

1. Selecting cost items.
2. Establishing total cost function of each model (TCi).
3. Comparing with each TCi.
4. Finding out Min TCi.

We take Rij value as the judgement standard of any two functions, and analyze its characteristics. The definition of Rij value is:

$$Rij = \frac{TCi}{TCj} \text{ , } i \neq j$$

That is

$$R12 = \frac{TC1}{TC2} \text{ , } R23 = \frac{TC2}{TC3} \text{ , } R13 = \frac{TC1}{TC3}$$

When Rij < 1, choose TCi; when Rij > 1, choose TCj. This study analyzes the influence on the Rij value by the change of each variable in order to realize its sensibility. Some relevant characteristic is listed as following:

1. The total cost of any model (i), Tci, can be taken as the basis criteria of alternative model when transferring modal.
2. The ratio of total cost from the two models, Rij, can be the basis criteria when transport method changing.
3. Through Rij value diagram, we can see clearly the influence from variables and distance L to the model.
4. There are different Rij values for the effects. That is, the same variable has different degrees of effect on different Rij value.
5. One variable has different degrees of effect on the same Rij value at different transport distances (L).
6. Different variables to one Rij value have different effect degrees of effect.

Table 7. Base value of each variable

Variable	Base value (N.T. dollars)	Variable	Base value
UIH	8500	RTM	0.00283
UIR	7500	RTK	0.00773
UIS	0	HR(hr)	6
UHY	1200	LR(km)	15
UDK	756	LS(km)	50
UHC	549	TR	0.005263
UWP	355	TS	0.021053
UM1	440	PC1	0.00828
UM2	274	PC2	0.00565
UM3	391	T1(hr)	1
UYD	59	T3(hr)	2
UST	310	HS(hr)	24
UIT	274		

note：The one within the parentheses is the unit of variable.

When considering the effect by the three transport methods to competitive distance simultaneously, we discuss it by dividing the distance into four parts, 0km~308km, 308km~431km, 431km~447km, and above 447km:

1. When the transport distance within 308km, R13 < R12 < 1.0, that is, (TC1/TC3) < (TC1/TC2) < 1.0. So, TC1 < TC2 < TC3, and the sequence of competitive advantageous position is highway > railway > ship.

2. When the transport distance between 308km to 431km, R23 < R13 < 1.0, that is, (TC2/TC3) < (TC1/TC3) < 1.0. So, TC2 < TC1 < TC3, and the sequence of competitive advantageous position is railway > highway > ship.
3. When the transport distance between 431km to 447km, R12 > R13 > 1.0, that is, (TC1/TC2) > (TC1/TC3) > 1.0. So, TC2 < TC3 < TC1, and the sequence of competitive advantageous position is railway > ship > →highway.
4. When the transport distance more than 447km, R13 > R23 > 1.0, that is, (TC1/TC3) > (TC2/TC3) > 1.0. So, TC3 < TC2 < TC1, and the sequence of competitive advantageous position is ship > railway > highway.

Therefore, we get the following graph (Fig-3):In Fig 3, point A's logarithm on abscissa is 308km, that is, container transport distance is within 308km, and method 1 (highway) is more competitive than method 2 (railway); point B's logarithm on abscissa is 431km, that is, container transport distance is within 431km, and method 1 (highway) is more competitive than method 3 (ship); point C's logarithm on abscissa is 447km, that is, container transport distance is within 447km, and method 2 (railway) is more competitive than method 3 (ship). From this, railway transport method in Taiwan area seems to be more competitive.

Moreover, for convenience to be compared, we quantified the effect and classify them with degrees (as Table 8.):

1. A degree means that there are at least two Rij values while on the same Rij being of at least variation of 8%.
2. B degree means that there are at least one Rij value being of variation of 3%~8%.
3. C degree is under 3%.

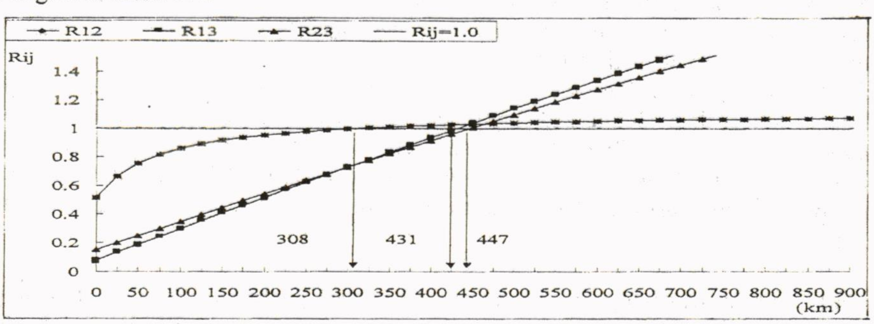

Fig-3 Competitive distance of the three transport methods

Table 8.Effect degree of each variable under different method and distance

		R_{12}	R_{13}	R_{23}
Short distance (75KM)	A Degree	RIH、RIR and RMi	RIH、RDK and HS	RIR、RDK、RMi and HS
	B Degree	RTM、RTK、LR and PCi	RMi、RST、RTM、LR、PCi and TI	LS and LR
Middle distance (200KM)	A Degree	RIH、RIR and RMi	RIH、RDK、RMi、RTM and HS	RIR、RDK and HS
	B Degree	RTM	LS	RIH、RTM、LR and LS
Long distance (400KM)	A Degree	RIH、RIR and RMi	RIH、RDK、RMi、RTM and HS	RIR、RDK、RTM and HS
	B Degree	-	LS and TS	RIH、LS and TS

There are lots of constitutions of the main variables, and in this paragraph we select some ratios from RIH, RIR and RIS (RIR/RIH, RIS/RIH) to discuss.

(一)RIR / RIH

From Fig 3 we can know that railway transport of Kaohsiung Port-Puxin, Taoyuan(360km) and Kaohsiung Port-Keelung Port(420km) is feasible theoretically (RIR / RIH = 0.63 , then RIH = 100%, RIR=100%), but now passenger transport has occupied the main part of railway capacity, so the capacity for cargo transport is not sufficient. Besides that, the issues about insufficiency or lack of related facilities, waste time of loading and unloading and low efficiency make shipping companies prefer highway transport. If there are complete facilities on the container distribution station near railway and shipping companies have willing to use it, only transport cost does not satisfy shipping companies, then RIR has to be reduced adequately.

1. For more feasible toward railway transport between Kaohsiung Port to Keelung area (420km), RIR/RIH=0.63 (RIH=100%, RIR=100%) can be RIR/RIH=0.71 (RIH=100%) or RIR/RIH=0.66 (RIR=80%) or RIR/RIH=0.61 (RIR=60%).
2. For more feasible toward railway transport between Kaohsiung Port to Puxin, Taoyuan (360km), RIR/RIH=0.63 (RIH=100%, RIR=100%) can be RIR/RIH=0.69 (RIH=100%) or RIR/RIH=0.63 (RIR=80%) or RIR/RIH=0.58 (RIR=60%).
3. For more feasible toward railway transport between Kaohsiung Port to Taichung Port (240km), RIR/RIH=0.63 (RIH=100%, RIR=100%) can be RIR/RIH=0.59 (RIH=100%) or RIR/RIH=0.56 (RIR=80%) or RIR/RIH=0.495 (RIR=60%).

(二)RIS / RIH

From Fig 3 we can know that the ratio of original ship transport cost and highway transport cost is 0.26 (RIH=100% , RIS=100%).

1. If RIH unchanged, it's feasible to transport by ship between Kaohsiung Port and Keelung Port (430km) when RIS/RIH=0.205. And using RIS/RIH=0.205 to be the basis, if RIH increases to be 150% , the competitive distance changes from 430km to 370km; if RIS reduces to be 70%, RIS/RIH=0.16.
2. If RIH unchanged, RIS become 70% or 50%(ratio is 0.18 and 0.13) and their competitive distance longer than 430km, and ship transport between Kaohsiung Port and Keelung Port (430km) is still not feasible. If RIH increases to be 125%, the ratio of RIS/RIH reduces from 0.26 to 0.14 (RIH=125%, RIS=70%) or 0.1 (RIH=125%, RIS=50%), and ship transport is very feasible. Therefore, the key point is the variation of highway transport cost.

Similarly, for the feasibility of ship transport between Kaohsiung Port and Taichung Port (250km), the ratio of ship transport cost and highway transport cost (RIS/RIH) reduces from 0.26(RIH=100%, RIS=100%) to be 0.09(RIH=200%, RIS=70%) or 0.06(RIH=200%, RIS=50%).

6. CONCLUSIONS

The paper constructs a competitive model, for the inland container through transport with the theory of the gravity model to study the characteristic of the container through transport. We also combine container loading and unloading operation method and transport method to establish transport-method alternative model, and set up total cost function of each model and determinative criteria. Through analysis of competitive distance at the same time, classify the effect variables into three groups as the basis of transport -method selection. The result of this research is showed as follows:

1. The sources of Taiwan containers are mostly in the north, about sixty percent of total volume; the middle is about fifteen percent; the south is about twenty-five percent.
2. With the analysis of the transportation distance and transportation model, the range of hinterland around Keelung port is concentrated; but around Kaohsiung port it is not concentrated; around Taichung port it has been increasingly concentrated in recent two or three years.
3. By the analysis of the through transport model:
   (1).Due to the insufficient capacity of Keelung Port and the container sources mostly located in the north of Taiwan, the waiting time for ship space become longer so that the businessmen would rather berth at Kaohsiung port, which is a self-rent container port.
   (2) With the element of the load-unload expense, at Keelung ship has to pay the extra fee for priority berthing because the Keelung port is public. And the different charging system of Kaohsiung port makes the load-unload expense lower.
   That,s why there is a huge amount of the inland container transport flow trough Taiwan area .
4.When we consider to transfer highway transport to railway or ship transport, the main effect factors are highway transport cost, railway transport cost, ship transport cost, container berth mooring cost, container handling cost, machine using cost, cargo time, trailer waiting cost and basic cost of highway transport.
5.If there is a railway near both two ends where cargoes are located, as to transferring the method of transportation, from highway to railway is more feasible than from highway to ship. And its competitive distance is around 310km in Taiwan area.
6.As to ship transport, ship-waiting time is about 3~7 days, so it is more feasible to replacing highway transport by ship transport on importing in Taiwan area.

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