Competition Model with Development Policies for Emerging Ports: Case Study of the Mainland of China

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Current status of ports in mainland China

- 112 primary ports
- Five port clusters:
  - The Bohai Bay port cluster
  - The Yangtze River Delta port cluster
  - The southeastern coastal port cluster
  - The Pearl River Delta port cluster
  - The southwestern coastal port cluster
1 Introduction

Cargo throughput of coastal ports in China (billion tons)

Source: Statistical communiqué of the People’s Republic of China on the 2012 national road and waterway transportation development
1 Introduction

Top 10 container terminals in world (million TEUs)

<table>
<thead>
<tr>
<th>No.</th>
<th>PORT</th>
<th>COUNTRY</th>
<th>2012</th>
<th>2011</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Shanghai</td>
<td>China</td>
<td>32.53</td>
<td>31.74</td>
<td>29.07</td>
</tr>
<tr>
<td>2</td>
<td>Singapore</td>
<td>Singapore</td>
<td>31.65</td>
<td>29.94</td>
<td>28.43</td>
</tr>
<tr>
<td>3</td>
<td>Hong Kong</td>
<td>China</td>
<td>23.11</td>
<td>24.22</td>
<td>23.70</td>
</tr>
<tr>
<td>4</td>
<td>Shenzhen</td>
<td>China</td>
<td>22.94</td>
<td>22.57</td>
<td>22.51</td>
</tr>
<tr>
<td>5</td>
<td>Pusan</td>
<td>Korea</td>
<td>17.04</td>
<td>16.19</td>
<td>14.19</td>
</tr>
<tr>
<td>6</td>
<td>Zhoushan</td>
<td>China</td>
<td>16.83</td>
<td>14.69</td>
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<tr>
<td>7</td>
<td>Guangzhou</td>
<td>China</td>
<td>14.74</td>
<td>14.40</td>
<td>12.55</td>
</tr>
<tr>
<td>8</td>
<td>Qingdao</td>
<td>China</td>
<td>14.50</td>
<td>13.02</td>
<td>12.01</td>
</tr>
<tr>
<td>9</td>
<td>Dubai</td>
<td>UAE</td>
<td>13.28</td>
<td>13.00</td>
<td>11.60</td>
</tr>
<tr>
<td>10</td>
<td>Tianjin</td>
<td>China</td>
<td>12.30</td>
<td>11.50</td>
<td>10.08</td>
</tr>
</tbody>
</table>

Source: UNCTAD, review of maritime transport, report 2012
1 Introduction

In order to stimulate regional economy, a series of preferential policies have been launched by local governments in coastal area to support port construction.
1 Introduction

Are there any problems hidden by the prosperous picture?
1 Introduction

- In 2006, in order to regulate the development of ports, Chinese central government issued *Allocation Plan of China’s Coastal Ports*.

- However, the plan seems not to be strictly followed.

- A great number of the small and medium-sized ports have overestimated their competitiveness, and are planning to become internationally large-scale ports in spite of their congenital deficiencies.
1 Introduction

How the problem come into being?

- Confusion in Development Strategy
- Overlapping Functions
- Low-level Repeated Construction
- Imbalanced utilization among ports
1 Introduction

Ports in the Bohai Bay Area

- 12 ports.
- Average distance: 127 km.
- Shortest distance: 20 km.
- Most of them transport the same kind of goods -- large bulk cargo and container.
1 Introduction

Capacity Utilization in 2011

Container throughput (million TEUs)
1 Introduction

Capacity Utilization in 2011 (ports below 1 million)
1 Introduction

Capacity Utilization in different port groups

- More than 50% of small and medium-sized ports have low rates.
- Most of the large-sized ports (with more than 500 million TEUs of throughout) have high rates.

- **Small-sized ports:**
  
  *beyond the requirements*

- **Large-sized ports:**
  
  *behind the requirement*
1 Introduction

✓ Why shippers would rather choose large ports, which are over-used, than small or medium-sized ports, which have abundant capacity?

✓ What are the main factors in determining port competitiveness?

✓ How much competitiveness can an emerging port get?

✓ What strategies it can take to increase its competitiveness?

✓ And what kind of port it is expected to be in the future?
Can an emerging port realize its dream of becoming an international port?
Port hinterland (also known as port market area) is a performance indicator to gauge the competitiveness of a port.

Factors for port hinterland selection

- Service frequency
- Inspection & Quarantine, Customs
- Land-side transportation
- Port efficiency
2 Analysis of Factors

Service frequency

- Ship service frequency
- Waiting time
2 Analysis of Factors

- Customs regulations and procedure
- Procedure of commodity inspection and quarantine
- Time
- Cost and tariff
2 Analysis of Factors

- Location and natural conditions
- Inland transportation network availability and accessibility
- Distance or time
- Cost between ports and hinterland
2 Analysis of Factors

Port efficiency

- Handling efficiency
- Transshipment efficiency
- Port cost
2 Analysis of Factors
3 Competition Model

Problem description

Hinterland $H_1$

Hinterland $H_2$

Overlapping area

$P_1$

$P_2$
3 Competition Model

Typical Land-side Operational Procedures in mainland China

Simple procedure
- Booking ship space
- Inspection and Quarantine (IQ)
- Transit in land-side
- Handling process

Local IQ
- Booking ship space
- IQ
- Transit in land-side
- Inspection and Quarantine (IQ)
- Port customs
- Handling process

Local customs
- Booking ship space
- IQ
- Local customs
- Transit in land-side
- Port customs
- Handling process

Dry port
- Booking ship space
- IQ
- Local customs
- Transit in land-side
- Handling process

Note: IQ stands for Inspection and Quarantine
3 Competition Model

We assume that:
✓ All shippers will choose the procedure of Local customs;
✓ The procedure of Dry port is a special case of the Local customs.

Note: IQ stands for Inspection and Quarantine
3 Competition Model


- terminal
  - transshipment cost
  - transfer time

- transportation
  - time
  - cost

3 Competition Model

More considerations on land-side procedure

- Ending time
- Handling process
- customs transferring

- Applying to the customs
- Applying to IQ
- Waiting at freight yard
- Booking ship space (Starting time)

- Starting time
- Ending time
- Handling process

- Origin area (Freight yard)
- Destination area (Port)
- Destination area (Port)
- Origin area (Freight yard)

- transportation
3 Competition Model

Time and cost analyses of Land-side Procedure

- **Generalized Cost for waiting a ship** \((c_w)\)
  - Cost: booking shipping space \((F_w)\)
  - Time: waiting for a ship \((T_w)\)

\[
c_w = \alpha \cdot T_w + F_w
\]

where, \(\alpha\) is the VOT perceived by the intermodal operator.
3 Competition Model

Time and cost analyses of Land-side Procedure

Generalized Cost for customs clearance ($c_{cu}$)

- Commodity inspection and customs declaration ($T_{cu}$ and $F_{cu}$)
- Customs transferring ($T'_{cu}$ and $F'_{cu}$)

$$c_{cu} = \alpha \cdot (T_{cu} + T'_{cu}) + (F_{cu} + F'_{cu})$$

where, $\alpha$ is the VOT perceived by the intermodal operator.
3 Competition Model

Time and cost analyses of Land-side Procedure

Generalized cost for land-side transportation \( (c_{tr}) \)

- transit cost \( (F_{tr}) \)
  - transit cost of different mode \( (f_m) \)
- transit time \( (T_{tr}) \)
  - in-vehicle travel time \( t_{tr}^m \)
  - transfer time \( t_{tr}^s \)

\[
c_{tr} = \alpha \cdot T_{tr} + F_{tr} = \alpha \cdot \left( \sum_{m} t_{tr}^m + \sum_{s} t_{tr}^s \right) + \sum f_m
\]

where, \( m \) is the transportation mode, \( s \) is transfer node.
3 Competition Model

Time and cost analyses of Land-side Procedure

Generalized cost for handling \( c_h \)

- handling time \( T_h \)
- transshipment cost \( F_h \)

\[ c_h = \alpha \cdot T_h + F_h \]

where, \( \alpha \) is the VOT perceived by the intermodal operator
3 Competition Model

Time and cost analyses of Land-side Procedure

- the generalized cost of the whole land-side procedure

\[ c_i = c_w^i + c_h^i + c_{cu}^i + c_{tr}^i \]
3 Competition Model

• The market share of port $i$ in hinterland $H$ can be approximated by the probability of the port being selected by shippers in this area from available port set $S$.

• Thus, the market share can be formed as follow:

$$MS_H^i = P_S^i = \Pr \left( c_i \leq c_j, \quad \forall j \in S \text{ and } i \neq j \right)$$
3 Competition Model

Utility ($U_i$): Deterministic and Random Utility Components

$$U_i = V_i + \varepsilon_i$$

Random Component

$$= -c_i + \varepsilon_i$$

Deterministic Component

Independently and Identically Distributed (IID) Gumbel

Actual generalized cost

$$c_i = c_w^i + c_h^i + c_{cu}^i + c_{tr}^i$$

$$P_S^i = \frac{\exp(-c_i)}{\sum_S \exp(-c_S)}$$
Putian Port -- an emerging port

- **Location:** southeastern coast of China
- **Current hinterland:** Fujian Province
- **Throughput:** 1.6 million TEU
- **Land-side transportation mode:** highway
A high speed railway -- Xiangpu Railway -- will connect Nanchang, capital of Jiangxi Province, and Putian Port, shortening the travel time in half.
4 Case Study

Export ports for Jiangxi Province

- **The existing ports**
  - Shanghai Port
  - Ningbo Port
  - Xiamen Port
  - Shenzhen Port
  - Fuzhou Port

- **The emerging port**
  - Putian Port
4 Case Study

- How much market share can Putian Port get now?
- Can the railway help Putian Port realize its dream of mega port?
- Which strategies can benefit the increase of its market share?
4 Case Study

Port competitive model:

\[ c_i = c^i_w + c^i_h + c^i_{cu} + c^i_{tr} \]

\[ MS^i_H = P^i_S = \Pr \left( c_i \leq c_j, \quad \forall j \in S \text{ and } i \neq j \right) \]

\[ MS^i_H = P^i_S = \frac{\exp \left( -c_i \right)}{\sum_{S} \exp \left( -c_i \right)} \]
4 Case Study

Performance of ports -- Service frequency

Without loss of generosity, we take ships to Rotterdam as an example to identify the difference of service frequency among these ports. The number of ship $N_s$ is counted from 10/24/2013 to 12/25/2013 (63 days).

Weekly service frequency:

$$f = \frac{N_s}{63 \times 7}$$
The annual container handing capacity $CAP_h$ (TEU/year) of ports comes from CHINA PORTS YEAR BOOK (2012).

Port efficiency (TEU/hour):

$$e = \frac{CAP_h}{365/24}$$
Miscellaneous fees will be charged at port along with transshipment. Here, we take a lump sum cost per unit based on data available.

Source: Regulations on Collection of Port Charges of the People's Republic of China (Domestic Trade Part) [http://www.gdcd.gov.cn/gfzj/20080826181024477_1.shtml](http://www.gdcd.gov.cn/gfzj/20080826181024477_1.shtml)
## 4 Case Study

### Commodity inspection and customs declaration

<table>
<thead>
<tr>
<th>Ports</th>
<th>Dry port in Jiangxi</th>
<th>Commodity inspection and customs declaration in Jiangxi Province</th>
<th>Customs transferring</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Time / days</td>
<td>cost/ USD</td>
</tr>
<tr>
<td>Xiamen</td>
<td>O</td>
<td>3</td>
<td>41</td>
</tr>
<tr>
<td>Ningbo</td>
<td>O</td>
<td>3</td>
<td>41</td>
</tr>
<tr>
<td>Shanghai</td>
<td>O</td>
<td>3</td>
<td>41</td>
</tr>
<tr>
<td>Shenzhen</td>
<td>O</td>
<td>3</td>
<td>41</td>
</tr>
<tr>
<td>Fuzhou</td>
<td>X</td>
<td>3</td>
<td>41</td>
</tr>
<tr>
<td>Putian</td>
<td>X</td>
<td>3</td>
<td>41</td>
</tr>
</tbody>
</table>

*Note: O indicates a dry port; X indicates not having dry port;*

4 Case Study

**Transportation** -- time and cost for railway

The cost for Chinese railway are calculated by data from the former Ministry of Railways’ website (http://www.12306.cn/mormhweb/hyfw/).

Railway transportation time $t_1$ (day)

$$t_1 = l / (33.2 \times 24)$$

Where $l$ demotes travel distance.
The cost $c_2$ (USD) and time $t_2$ (day) of transporting one TEU by Chinese highways:

$$c_2 = 5.5 \times 0.146l = 0.803l$$

$$t_2 = 0.0015l$$

Where $l$ demotes travel distance.

Relevant Sources: Wang X, Meng Q. (2011)
## 4 Case Study

### Transportation

<table>
<thead>
<tr>
<th>Ports</th>
<th>main transit mode</th>
<th>Distance/km</th>
<th>Time/days</th>
<th>cost/USD</th>
<th>Auxiliary transportation*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mode</td>
<td></td>
<td></td>
<td></td>
<td>Time/days</td>
</tr>
<tr>
<td>Xiamen</td>
<td>Railway</td>
<td>946</td>
<td>1.19</td>
<td>527.98</td>
<td>-</td>
</tr>
<tr>
<td>Ningbo</td>
<td>Railway</td>
<td>813</td>
<td>1.02</td>
<td>466.83</td>
<td>-</td>
</tr>
<tr>
<td>Shanghai</td>
<td>Railway</td>
<td>880</td>
<td>1.10</td>
<td>538.17</td>
<td>0.04</td>
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<tr>
<td>Shenzhen</td>
<td></td>
<td>946</td>
<td>1.19</td>
<td>645.37</td>
<td>0.04</td>
</tr>
<tr>
<td>Fuzhou</td>
<td></td>
<td>642</td>
<td>0.81</td>
<td>426.66</td>
<td>0.04</td>
</tr>
<tr>
<td>Putian</td>
<td>Highway</td>
<td>681</td>
<td>1.02</td>
<td>820.35</td>
<td>-</td>
</tr>
</tbody>
</table>

- In Xiamen port, Ningbo port and Fuzhou port, railway can reach ports directly or just outside the port.
- While, in Shanghai port and Shenzhen port, cargos cannot reach ports only by railway, thus an auxiliary transportation (Port Transportation Services by trailers are available.
## 4 Case Study

### Summary of parameters

<table>
<thead>
<tr>
<th>Ports</th>
<th>Port</th>
<th>Commodity inspection and customs declaration</th>
<th>Transportation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Waiting time days</td>
<td>Handling time days</td>
</tr>
<tr>
<td>Xiamen</td>
<td></td>
<td>1.21</td>
<td>0.31</td>
</tr>
<tr>
<td>Ningbo</td>
<td></td>
<td>1.21</td>
<td>0.29</td>
</tr>
<tr>
<td>Shanghai</td>
<td></td>
<td>0.88</td>
<td>0.15</td>
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<tr>
<td>Shenzhen</td>
<td></td>
<td>0.59</td>
<td>0.13</td>
</tr>
<tr>
<td>Fuzhou</td>
<td></td>
<td>1.75</td>
<td>1.42</td>
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<tr>
<td>Putian</td>
<td></td>
<td>7.88</td>
<td>2.42</td>
</tr>
</tbody>
</table>

Note: VOT=3USD/TEU
4 Case Study

Benchmark -- market share of Putian Port

- Xiamen Port and Ningbo Port have a strong competitiveness, the market share of them are higher than 19%.
- Putian Port have the weakest competitiveness, the market share of it is only 8.2%.
4 Case Study

- **Scenario I** – Improving land-side transportation system
- **Scenario II** – Improving the customs efficiency
- **Scenario III** – Improving the port operations
### Scenario I -- Improving land-side transportation system

**with / without Xiangpu Railway**

**Ports influenced by Xiangpu Railway**

- Fuzhou Port
- Putian Port

<table>
<thead>
<tr>
<th>Ports</th>
<th>without Xiangpu Railway</th>
<th>with Xiangpu Railway</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>time/days</td>
<td>cost/USD</td>
</tr>
<tr>
<td>Xiamen</td>
<td>1.19</td>
<td>527.98</td>
</tr>
<tr>
<td>Ningbo</td>
<td>1.02</td>
<td>466.83</td>
</tr>
<tr>
<td>Shanghai</td>
<td>1.14</td>
<td>538.17</td>
</tr>
<tr>
<td>Shenzhen</td>
<td>1.23</td>
<td>645.37</td>
</tr>
<tr>
<td><strong>Fuzhou</strong></td>
<td><strong>0.85</strong></td>
<td><strong>426.66</strong></td>
</tr>
<tr>
<td><strong>Putian</strong></td>
<td><strong>1.02</strong></td>
<td><strong>820.35</strong></td>
</tr>
</tbody>
</table>
4 Case Study

Scenario I -- Improving land-side transportation system

\[ MS^i_H = P^i_S = \frac{\exp(-c^i)}{\sum S \exp(-c^i)} \]

\[ c^i = c^i_w + c^i_h + c^i_{cu} + c^i_{tr} \]

\[ c_{tr} = \alpha \cdot T_{tr} + F_{tr} \]

Have a reduce on \( F_{tr} \) and \( T_{tr} \)
**Scenario I** -- Improving land-side transportation system

Railway, with the advantage of low transit cost, can improve the competitiveness of the connected ports.

The market share of Putian Port increases from 8.2% to 10.3%.
4 Case Study

**Scenario II** -- Improving the customs efficiency

<table>
<thead>
<tr>
<th>Ports</th>
<th>whether have dry port in Jiangxi</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xiamen</td>
<td>O</td>
</tr>
<tr>
<td>Ningbo</td>
<td>O</td>
</tr>
<tr>
<td>Shanghai</td>
<td>O</td>
</tr>
<tr>
<td>Shenzhen</td>
<td>O</td>
</tr>
<tr>
<td>Fuzhou</td>
<td>X</td>
</tr>
<tr>
<td>Putian</td>
<td>X</td>
</tr>
</tbody>
</table>

*Note: O indicates have a dry port; X indicates do not have a dry port;*

\[
MS_H^i = P_S^i = \sum_{S'} \exp(-c_i)
\]

\[
c_i = c_w^i + c_h^i + c_{cu}^i + c_{tr}^i
\]

\[
c_{cu} = \alpha \cdot (T_{cu} + T'_{cu}) + (F_{cu} + F'_{cu})
\]

Have a reduce on \(T'_{cu}\) and \(F'_{cu}\)

- **Case I** -- without dry port for Fuzhou Port and Putian Port
- **Case II** -- dry port for Fuzhou Port
- **Case III** -- dry port for Putian Port
- **Case IV** -- dry port for Fuzhou Port and Putian Port
4 Case Study

Scenario II -- Improving the customs efficiency

<table>
<thead>
<tr>
<th>Ports</th>
<th>Case I</th>
<th>Case II</th>
<th>Case III</th>
<th>Case IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuzhou</td>
<td>X</td>
<td>O</td>
<td>X</td>
<td>O</td>
</tr>
<tr>
<td>Putian</td>
<td>X</td>
<td>X</td>
<td>O</td>
<td>O</td>
</tr>
</tbody>
</table>

Note:  O indicates have a dry port;  
X indicates do not have a dry port;

Dry port operation can help Putian Port to increase the market share in Jiangxi Province.
Scenario III -- Improving operations of Putian port

Case 1: change of the port efficiency

\[ MS^i = P^i = \frac{\exp(-c_i)}{\sum_{s} \exp(-c_i)} \]

\[ c_i = c_w^i + c_h^i + c_{cu}^i + c_{tr}^i \]

\[ c_h = \alpha \cdot T_h + F_h \]

Have a change on \( T_h \)
Case 1: change of the port efficiency

- The increase of port efficiency can gain a higher share of market for the Putian port.
4 Case Study

Scenario III -- Improving operations of Putian port

Case 2: change of the service frequency

\[ MS_H^i P_S^i = \frac{\exp(-c_i)}{\sum_{S} \exp(-c_i)} \]

\[ c_i = c_w^i + c_h^i + c_{cu}^i + c_{tr}^i \]

\[ c_w = \alpha \cdot T_w + F_w \]

Have a change on \( T_w \)
Case 2: change of the service frequency

- Service frequency is highly sensitive to the market share of Putian Port.
## 4 Case Study

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Description</th>
<th>Sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Transportation improvement</td>
<td>★☆☆☆☆</td>
</tr>
<tr>
<td>II</td>
<td>Customs improvement</td>
<td>★★☆☆☆</td>
</tr>
<tr>
<td>III case 1</td>
<td>High port efficiency</td>
<td>★★★★☆</td>
</tr>
<tr>
<td>III case 2</td>
<td>High service frequency</td>
<td>★★★★★</td>
</tr>
</tbody>
</table>

Results show that the market share of the Putian Port is highly sensitive to factors as service frequency, customs efficiency, and is less sensitive to factors as the landside transportation time.
5 Conclusions

(1) Though several main ports have reached the top level of world-wide ports, there are more ports which have been in their difficult stage of development to their target of international mega port due to confusions at planning level in mainland China.

(2) It is difficult for many emerging ports in China to realize the dream of becoming internationally mega port. Main difficulties are as below.

- Low frequency of shipment schedule
- Low efficiency of customs operational procedure
5 Conclusions

(3) The most sensitive factor is also the most difficult factor.
• Service frequency is hard to increase in a short time

(4) It is urgent for most emerging ports to adjust its development to reasonable and feasible scheme.
• Specialized port
• Feeding port
Thank you!
4 Case Study

Scenario I -- Improving land-side transportation system

Case II: change of the average speed of Xiangpu Railway

\[ MS_H^i = P_s^i = \frac{\exp(-c_i)}{\sum_s \exp(-c_i)} \]

\[ c_i = c_w^i + c_h^i + c_{cu}^i + c_{tr}^i \]

\[ c_{tr} = \alpha \cdot T_{tr} + F_{tr} \]

Have a change on \( T_{tr} \)

![Graph showing market share vs. average speed and travel time](image.png)
4 Case Study

**Scenario I** -- Improving land-side transportation system

**Case II: change of the average speed of Xiangpu Railway**

- Time can be reduced by Xiangpu Railway, but it is limited.

- With this limited reduce, Xiangpu Railway cannot contribute too much to the market share of Putian Port.
Scenario I -- Improving land-side transportation system

Case III: change of the tariff of Xiangpu Railway

\[ MS_H^i = P_S^i = \frac{\exp(-c_i)}{\sum_s \exp(-c_s)} \]

\[ c_i = c_w^i + c_h^i + c_{cu}^i + c_{tr}^i \]

\[ c_{tr} = \alpha \cdot T_{tr} + F_{tr} \]

Have a change on \( F_{tr} \)
Scenario I -- Improving land-side transportation system

Case III: change of the tariff of Xiangpu Railway

- The reduction of the tariff rate of Xiangpu Railway will significantly improve the market share of Putian Port.

- Unfortunately, the traffic rate have a price floor, it can not reduce without consider the benefits of the railway.