

Container Logistic Transport Planning Model

Xin Zhang and Xiao-Min Shi
 Jiaxing University, Jiaxing, P.R. China

Abstract: The study proposed a stochastic method of container logistic transport in order to solve the unreasonable transportation’s problem and overcome the traditional models’ two shortcomings. Container transport has rapidly developed into a modern means of transportation because of their significant advantages. With the development, it also exacerbated the flaws of transport in the original. One of the most important problems was that the invalid transport had not still reduced due to the congenital imbalances of transportation. Container transport exacerbated the invalid transport for the empty containers. To solve the problem, people made many efforts, but they did not make much progress. There had two theoretical flaws by analyzing the previous management methods in container transport. The first one was the default empty containers inevitability. The second one was that they did not overall consider how to solve the problem of empty containers allocation. In order to solve the unreasonable transportation’s problem and overcome the traditional models’ two shortcomings, the study re-built the container transport planning model-gravity model. It gave the general algorithm and has analyzed the final result of model.

Keywords: Algorithms and analysis, container transport, gravity model

INTRODUCTION

The container transport was a modern way of transport to meet the needs of large-scale socialized production. It had the advantages which other transports could not be replaced. It had greatly improved the quality of transport for the realization of the full-mechanized. Its station capacity became greater, the transport system operating costs had been decreased significantly and the transportation efficiency had been greatly improved. The reason was that the container transport could achieve the organization directly clippers, express line transport. Therefore, more and more pieces of cargos were become to the container transport. The rate case had more than 80% from the 1990 (Li, 2010). Table 1 in this context, container transport had been rapid development far from other transport methods. Figure 1 (Clarkson Research Services, 2008) was the process diagram of the international container trade development from 1986 to 2008. Even after the world financial crisis in 2009, the container transport had embarked on also the steady course of development. In this sense, with the development of the economy, the goods would be transported in container. The process would be less and less than the bulk, low value-added raw materials and primary products had directly transported. With the development of the information technology and computer technology, the container transport had been rapidly developed.

Table 1: The proportion of containerization in the general cargo

Y	Proportion %	Y	Proportion %
1991	52.4	2000	66.2
1992	53.1	2001	67.7
1993	54.3	2002	69.5
1994	55.1	2003	71.1
1995	58.3	2004	73.8
1996	60.1	2005	75.2
1997	61.3	2006	77.4
1998	63.2	2007	78.8
1999	64.8	2008	79.6

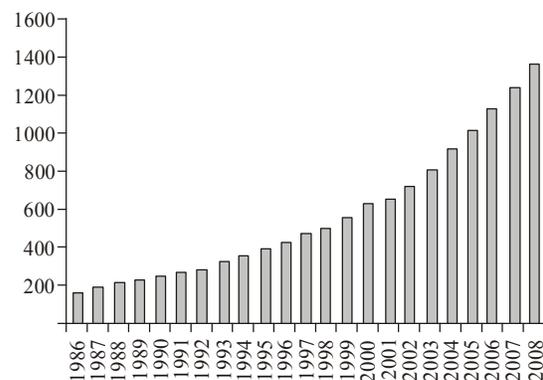


Fig. 1: The international container trade (million tons)

However, there were still some issues in the container transportation for the current production conditions, methods and restraint concepts in practice. One of the important questions was how to speed up the container flow, reduce empty containers and improve the utilization of container. In recent years, container

liner management cost had become the second largest operating cost in the cost of the project, which was about 1/5 from the total cost of shipping company in cost point of view. Among them, the cost of empty container accounted for about 1/4. On the other hand, in the cargo point of view, the volume of empty containers in the global perspective was one-fifth of the total container. According to statistics, empty containers were about 18, 20 and 24%, respectively of the Long Beach, Seattle and San Diego port's container throughput. At the same time, some major European ports' empty containers were also about 18% of the total throughput, such as port of Stockholm, Rotterdam, Nantes, Hamburg. Especially, China's problem was more serious in the proportion of empty containers for the imbalance in the import and export of goods and others were slightly better such as Japan, South Korea in Asia. Therefore, it had become an urgent optimize problem in the global how to transport empty containers.

So, the new method should be proposed in order to solve the unreasonable transportation's problem and overcome the traditional models' two shortcomings. Moreover, the method should be random and dynamic.

LITERATURE REVIEW

Currently, the typical model of the empty containers transported was:

$$C = \min(\sum_j \sum_i c_{ij}x_{ij} + \sum_j R_j y_j).$$

But, the model had two theoretical flaws. The first one was the default empty containers inevitability. At this point, it could not be the theoretically optimal. The second one was that they did not overall consider how to solve the problem of empty containers allocation. They only considered the empty containers' causes rather than from the integrity of the system. Generally, it was not brought back to the originating point for the re-select the transport routes as long as the container came into the transport process. So, the redistribution of the actual traffic in the transport network would be postponed. The next part was largely decided by the transport process of last part. Traditional models completely ignored the time lag.

In order to solve the unreasonable transportation's problem and overcome the traditional models' two shortcomings, the study put forward a solution of container transport planning model-Gravity model.

- **Question:** With this modern mode of transport containers, the problem that the imbalance of economic development led to the waste of resources caused by the imbalance goods during the transportation became more serious. One of

important reasons was that container transport which became a reality could not re-select the shipping lines without depletion resources, whether there was any limit. So, the redistribution of the actual traffic in the transport network would be postponed. The practice needed design an effective program. It could reduce depletion and make up for the shortcomings of existing models. With the same time, it could give the volume of container on each path.

- **Quantitative analysis:** Variables when they were designed could reduce container transport impact of the delay and ensure that enterprises got the most benefit. In other words, they could ensure to maximize transport volume and minimize transport cost. So, these variables should include the cost variable c and the actual flow q that were assigned to each path. And then, the function expression posed by these variables was established after excluding the time-delay.
- **Model assumptions:** Container transportation network G was connected. That is to say, there must have at least a chain from start to finish between any two nodes. In fact, the assumption was set up because there must exist one way to link between different places.
- The container traffic of two nodes was not restricted by the path capacity. (This study mainly studied the companies' microscopic behavior during the container transport planning period from the perspective of the container operator).
- It was only considered the container capacity of the dissipated place instead of the generated place.
- The same level of transport network nodes would be studied. Interior of nodes' problem was the next level of the transport network.
- The cost difference expressed the owned containers, container leasing, heavy boxes and empty containers.
- **Model:** The letter i, j used to indicate nodes of the container transport network. The z_{ij} indicated the path e_{ij} gains. It used to express the gravity function between the nodes i and the node j . The sum of the gravity function must obtain to maximum value in order that program could obtain the optimal results. So, the container planning model was:

$$Ob. \quad Z = \max \sum_j \sum_i z_{ij} = \max \sum_j \sum_i (\lambda_{ij} - c_{ij}) q_{ij}$$

$$s.t. \quad \begin{cases} c_{ij} \geq 0 \\ Q_{ij} \geq q_{ij} \geq 0 \\ i, j \in N \quad i \neq j \end{cases} .$$

where,

- Q_{ij} = The attract container volume from node i to the destination j
- c_{ij} = The container unit cost of the path e_{ij} and the destination j
- q_{ij} = The actual flow of container in the path e_{ij} during the planning period
- λ_{ij} = Unit revenue between node i and j . It was constant in the model (Freight was not the scope of the study)

- **Modes solution:** Actually, it must maximize the actual flow q_{ij} and minimum the unit cost c_{ij} if the model wanted to obtain the optimal value. So, it could be solved through the weighted graph method (Papa *et al.*, 2009; Asahiro *et al.*, 2011; Duarte *et al.*, 2011; Xin, 2010.) when parameters were determined.

First, the parameter q_{ij} was assigned zero. And then, the augmenting chain, which could increase the flow, was found under the total cost was the least from start to finish. The least cost flow $q^{(1)}$ could be found after that the augmenting chain was increased the flow. The second, the augmenting chain would be found during the network $q^{(1)}$. It could draw the new least cost flow $q^{(2)}$ by duplication the previous step. And so, it was not stop until the augmenting chain was no exists. The resulting flow was the optimal container traffic under the minimum cost of a balanced transport. How did solve the augmented chain?

Here needed construct a new weighted graph according to the conditions of the augmenting chain during the transport network. Paths of the network were become a forward arc e_{ij} and a reverse arc e_{ji} . The unit cost of each path could not change. The weight of each path was determined on the following principles:

$$w_{ij} = \begin{cases} c_{ij} & (q_{ij} < Q_{ij}) \\ +\infty & (q_{ij} = Q_{ij}) \end{cases} \quad (1)$$

$$w_{ji} = \begin{cases} -c_{ij} & (q_{ij} > 0) \\ +\infty & (q_{ij} = 0) \end{cases} \quad (2)$$

The arc was omitted when the weight was $+\infty$.

MODEL DEMONSTRATION

There was a container transport network $G(V(6), E(9))$ which included 6 nodes and 9 edges. The data of Q_{ij} , C_{ij} was seen in Table 2 and 3 and it was a random series in order to test the model's versatility. The value q_{ij} was zero at beginning. What was the maximum of gravity model Z during the planning period that there had not invalid transportation? It could transfer to solve the value of q_{ij} when the value C_{ij} was minimized. The orderly array on the arc expressed as (q_{ij}, Q_{ij}, C_{ij}) .

Table 2: The value of Q_{ij} (*100) on the path e_{ij}

		J						
		s	1	2	3	4	t	
Q_{ij}	i	s	--	20	15	--	--	--
	1	--	--	--	--	8	--	--
	2	--	--	5	--	2	7	--
	3	--	--	--	--	--	--	10
	4	--	--	--	--	8	--	4
	t	--	--	--	--	--	--	--

Table 3: the value of C_{ij} (*100) on the path e_{ij}

		J						
		s	1	2	3	4	t	
C_{ij}	i	s	--	5	1	--	--	--
	1	--	--	--	--	3	--	--
	2	--	2	--	6	3	--	--
	3	--	--	--	--	--	--	4
	4	--	--	--	7	--	--	2
	t	--	--	--	--	--	--	--

Table 4: weight W_{ij} on the path e_{ij}

		J						
		s	1	2	3	4	t	
W_{ij}	i	s	--	5	1	--	--	-
	1	$+\infty$	--	$+\infty$	3	--	--	-
	2	$+\infty$	2	--	6	3	--	-
	3	--	$+\infty$	$+\infty$	--	$+\infty$	4	4
	4	--	--	$+\infty$	7	--	--	2
	t	--	--	--	$+\infty$	$+\infty$	--	-

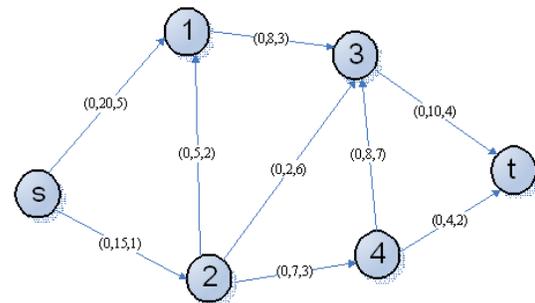


Fig. 2: $q^{(0)} = 0$

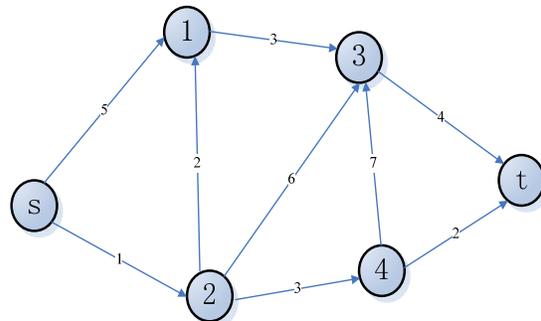


Fig. 3: $w(q^{(0)})$

The network flow graph q^0 could be generated according to the q_{ij} (Fig. 2). And then, weights w_{ij} (Table 4) of all paths e_{ij} could be determined according to the formula (1) and (2).

Table 5: Weight W_{ij} on the path e_{ij}

		J					
		s	1	2	3	4	t
Q_{ij}	s	--	5	1	--	--	--
i	1	+∞	--	+∞	3	--	--
	2	-1	2	--	6	3	--
	3	--	+∞	+∞	--	+∞	4
	4	--	--	-3	7	--	+
	t	--	--	--	+∞	-2	∞

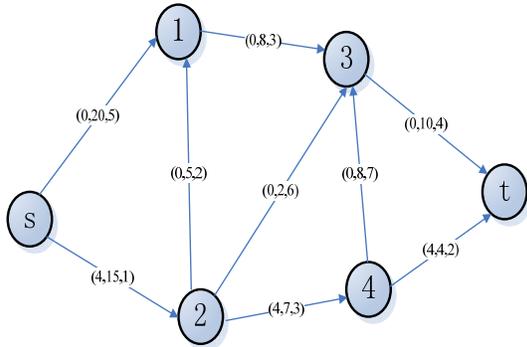


Fig. 4: $q^{(1)} = 4$

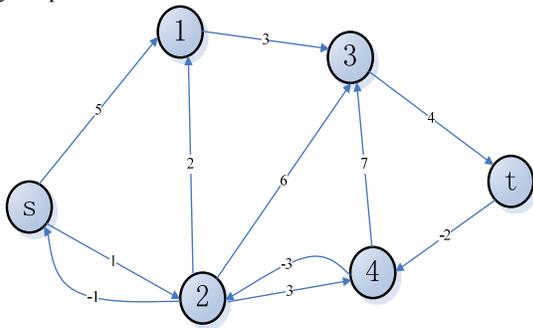


Fig. 5: $w(q^{(1)})$

There could be easy to find the minimum cost augmenting chain $s \rightarrow 2 \rightarrow 4 \rightarrow t$ according to the Fig. 3. The total cost was $6(1+2+3=6)$. The flow (Δ) could be increased was minimum (15, 7, 4). So, $\Delta = \min(15, 7, 4) = 4$. Every edges would be increased the unit 4 flow in the chain $s \rightarrow 2 \rightarrow 4 \rightarrow t$. There would get a new network flow diagram $q^{(1)}$. The network flow $q^{(1)}$ was 4 (Fig. 4).

Weights w_{ij} (Table 5) of all paths e_{ij} , when $q^{(1)} = 4$, could be determined according to the formula (1) and (2). The weight graph was $w(q^{(1)})$ (Fig. 5).

There could be easy to find the minimum cost augmenting chain $s \rightarrow 2 \rightarrow 1 \rightarrow 3 \rightarrow t$ according to the Fig. 5. The total cost was $10(1+2+3+4 = 10)$. The flow (Δ) could be increased was minimum (11, 5, 8, 10). So, $\Delta = \min(11, 5, 8, 10) = 5$. Every edges would be increased the unit 5 flow in the chain $s \rightarrow 2 \rightarrow 1 \rightarrow 3 \rightarrow t$. There would get a new network flow diagram $q^{(2)}$. The network flow $q^{(2)}$ was 9. (Fig. 6)

Table 6: weight W_{ij} on the path e_{ij}

		J					
		s	1	2	3	4	t
Q_{ij}	s	--	5	1	-	--	--
i	1	+∞	--	-2	3	--	--
	2	-1	+∞	--	6	3	--
	3	--	-3	+∞	-	+∞	4
	4	--	--	-3	7	--	+
	t	--	--	--	4	-2	∞

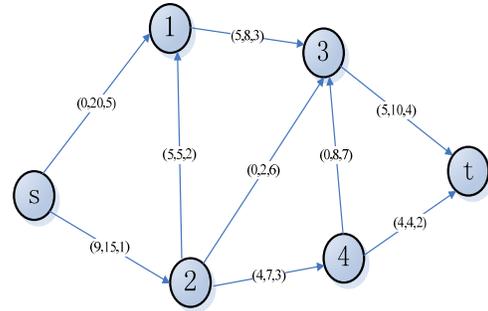


Fig. 6: $q^{(2)} = 9$

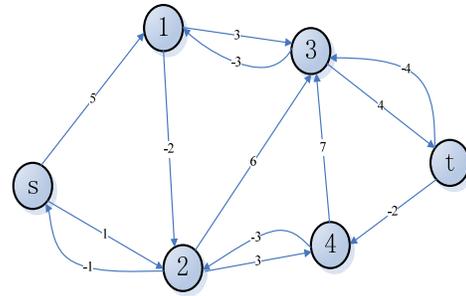


Fig. 7: $w(q^{(2)})$

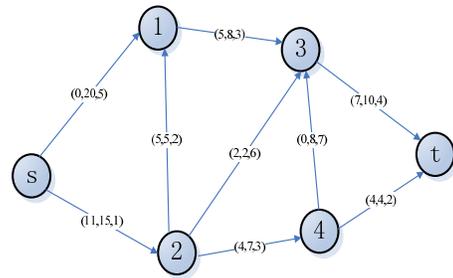


Fig. 8: $q^{(2)} = 11$

Weights w_{ij} (Table 6) of all paths e_{ij} , when $q^{(2)} = 9$, could be determined according to the formula (1) and (2). The weight graph was $w(q^{(2)})$ (Fig. 7).

There could be easy to find the minimum cost augmenting chain $s \rightarrow 2 \rightarrow 3 \rightarrow t$ according to the Fig. 7. The total cost was $11(1+6+4 = 11)$. The flow (Δ) could be increased was minimum (6, 2, 5). So, $\Delta = \min(6, 2, 5) = 2$. Every edges would be increased the unit 2 flow in the chain $s \rightarrow 2 \rightarrow 3 \rightarrow t$. There would get a new network flow diagram $q^{(3)}$. The network flow $q^{(3)}$ was 11 (Fig. 8).

Table 7: Weight W_{ij} on the path e_{ij}

		J					
		s	1	2	3	4	t
Q_{ij}	s	--	5	1	--	--	--
	1	$+\infty$	--	2	3	--	--
	2	-1	$+\infty$	-	$+\infty$	3	--
	3	--	-3	6	--	$+\infty$	4
	4	--	--	3	7	--	+
	t	--	--	-	-4	-2	∞

Table 8: Weight W_{ij} on the path e_{ij}

		J					
		s	1	2	3	4	t
Q_{ij}	s	--	5	1	--	--	--
	1	$+\infty$	--	2	$+\infty$	--	--
	2	-1	$+\infty$	-	$+\infty$	3	--
	3	--	-3	6	--	$+\infty$	+
	4	--	--	3	7	--	∞
	t	--	--	-	-4	-2	--

Table 9: The value of Q_{ij} (*100) during the planning period

		J					
		s	1	2	3	4	t
Q_{ij}	s	--	3	11	--	--	--
	1	--	--	--	8	--	--
	2	--	5	--	2	4	--
	3	--	--	--	--	--	10
	4	--	--	--	0	--	4
	t	--	--	--	--	--	--

The total cost was $12(5+3+4 = 12)$. The flow (Δ) could be increased was minimum (20, 3, 3). So, $\Delta = \min(20, 3, 3) = 3$. Every edges would be increased the unit 3 flow in the chain $s \rightarrow 1 \rightarrow 3 \rightarrow t$. There would get a new network flow diagram $q^{(4)}$. The network flow $q^{(4)}$ was 14 (Fig. 10).

Weights w_{ij} (Table 8) of all paths e_{ij} , when $q^{(3)} = 14$, could be determined according to the formula (1) and (2). The weight graph was $w(q^{(4)})$ (Fig. 11).

There did not have the minimum cost augmenting chain from the Fig. 11 because of no augmenting chain. So, the algorithm ended. The value q_{ij} in the Fig. 10 was the optimal result.

CONCLUSION

The actual container traffic q_{ij} of container management operator was concluded during the planning period from the gravity model (Table 9) there had two conclusions. The empty container problem solved must consider the whole system instead of a single transport. It was only way to solve the delay problem. The second conclusion was that the company did not ensure to operate every line and transport the maximum amount every path.

REFERENCES

Asahiro, Y., E. Miyano and H. Ono, 2011. Graph classes and the complexity of the graph orientation minimizing the maximum weighted out degree. *Discrete Appl. Math.*, 159: 498-508.

Clarkson Research Services, 2008. *Review of Maritime Transport: Shipping Review Database*. Geneva, New York, UN, pp: 101.

Duarte, A., M. Laguna and R. Marti, 2011. Tabu search for the linear ordering problem with cumulative costs. *Comput. Optim. Appl.*, 48: 697-715.

Li, P., 2010. *China Shipping Market Analysis and Counterproposal Study of Transpacific Container Shipping Liner*. Dalian Maritime University, 13.

Papa, J.P, A.X. Falcao and C.T.N. Suzuki, 2009. Supervised pattern classification based on optimum-path forest. *Int. J. Imag. Syst. Techy.*, 19: 120-131.

Xin, Z., 2010. Traffic-induced model. 10th Proceeding of the International Conference on Intelligent Computation Technology and Automation, Washington, DC, USA, 3: 1084-1086.

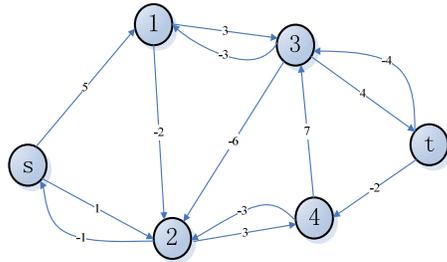


Fig. 9: $W(q^{(3)})$

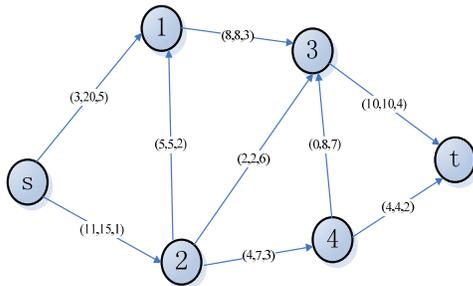


Fig. 10: $q^{(4)} = 14$

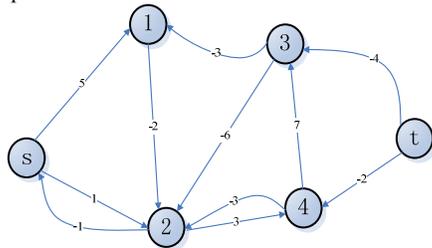


Fig. 11: $W(q^{(4)})$

Weights w_{ij} (Table 7) of all paths e_{ij} , when $q^{(3)} = 11$, could be determined according to the formula (1) and (2). The weight graph was $w(q^{(3)})$ (Fig. 9).

There could be easy to find the minimum cost augmenting chain $s \rightarrow 1 \rightarrow 3 \rightarrow t$ according to the Fig. 9.