Available online at www.sciencedirect.com

SciVerse ScienceDirect

Physics Procedia 33 (2012) 827 – 832

Physics Procedia

2012 International Conference on Medical Physics and Biomedical Engineering

Optimization for Hub-and-Spoke Port Logistics Network of Dynamic Hinterland

JI Ming-Jun, CHU Yan-Ling

Transportation Management College, Dalian Maritime University, 116026, China
E-mail: jmj012001@yahoo.com.cn (Dr. Ji)

Abstract

The port logistics and its regional economic react on each other and develop in unison. This paper studies the Hub-and-Spoke port logistics network which is a transportation system between the sea routes and ports hinterland transport routes. An optimization model is proposed with the objective of the total transportation cost in the regional port group based on the conditions of dynamic hinterland. This paper not only ensures every port in the hub-and spoke port logistics network to achieve its maximum economic benefits, but also makes the entire system get the minimum total transportation cost in the view of quantitative point. In order to illustrate the validity of the model, the example was solved. The results show that the model is feasible. Furthermore, the competitiveness power of the port, the demarcation of hinterland and the traffic capacity are changed dynamically in the model, which is closer to the real system.

Keywords: Dynamic hinterland, Port logistics, Hub-and spoke network, Optimization model

1 Introduction

With the development of China's economic, modern port logistics industry has been developing rapidly. The hinterland of the harbor, an important factor of the port in competitiveness, also will be changed accordingly. The hinterland of the harbor is consisted of two parts: Land-based economic hinterland and maritime economic hinterland [1], and the traditional land-based hinterland into the direct and dynamic hinterland are gradually transformed to a unified dynamic hinterland. Hub-and spoke port logistics transportation network refers to the sea routes between every port and transportation system between every port and its economic hinterland in the logistics transportation system of port group, as in shown in figure 1.

 doi:10.1016/j.phpro.2012.05.141

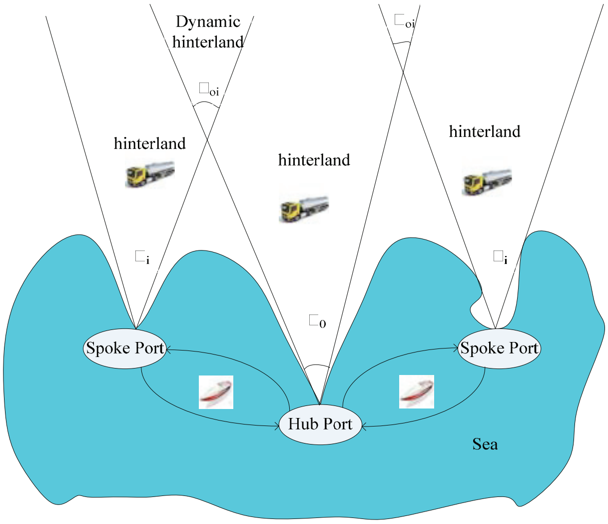

Figure1 Hub-and Spoke Port Logistics Transport Network

For a whole system of the regional ports group, we must consider the overall system optimization and coordination, but also to meet the individual port's economic development goals. For the study of port – hinterland in domestic, it begins in the mid of 1980s. Yang[2] combined gravity model and the fuzzy comprehensive evaluation model to determine the attractiveness and the scope of services of the ports to its hinterlands. Bai[3] deeply analyzed the relationship of port and hinterland, and build hinterland segmentation method based on Attractive Force Model. Fang[4] discussed the influence of the port to its adjacent core hinterland, marginal hinterland and transitive hinterland from the Pearl River Delta commercial port open angle, showed that ports open plays an important role in the city and its core hinterlands. In the aspect of studying the port group as a whole system, Wang[5] studied an individual port choose its hinterland in a static optimal condition, and when it refers to taking port group system as a whole and Bi-level programming problem, the study is mainly focused on the evolution of the Port group's spatial structure. Lu[6] studied a port logistics center and its development. Zhao[7] established an urban traffic flow control prototype system based on Multiagent. Wei[8] established the Bi-Level Programming Model for the transport modes selection and traffic distribution in a comprehensive transport modes. Feng[9] established a Bi-Level Programming Model based on Multi-agent simulation, and solved the overall coordination of optimization problem of size, structure, and layout of the Port group system. Guo[10] studied the layout of the domestic coastal container ports based on variety of transport modes. Zhen[11] expounded the elements, functions and optimal principles of port logistics. Matthew[12] analysis the ports selection based on mathematical model. Hoyle[13] conducted a case study about the region competition within the port group in East Africa and other developing countries. Hayuth[14] discusses the rationalization and decentralization in the U.S. container port system.

In summary, the current study of complicated port logistics system, some focused on a single port structure and layout optimization, or mainly based on qualitative analysis and static optimization, which can not meet the integrity and dynamic nature of requirements for port cluster system. On the basis of previous studies, taking into account the dynamics of the hinterland of each port range in the two port logistics transport system, this paper establishes a multi-objective programming model, which contains the total transportation cost for the two stage logistics of transport systems, and the economic benefits of each port in the dynamic choice of an economic hinterland. So it meets the requirements of regional port cluster in integrity and dynamic. Model gains settlement of three aspects finally: (1) the dynamic hinterland range in individual port; (2) the land-based transport capacity of the whole transportation system for each hinterland; (3) the traffic as well as the corresponding transportation capacity between ports in Sea route system.

2 Mathematical model

A. Definition

0 indicates the hub port; i indicates the spoke port.

Dynamic hinterland: the dynamic hinterland range of port i is based on: set the intersection of the spoke port i and the Hub port 0 as the vertex, take R_{0i} as radius and θ_{0i} as Central angle, the sector region of the direction of radiation to the interior, shown in Figure 2.

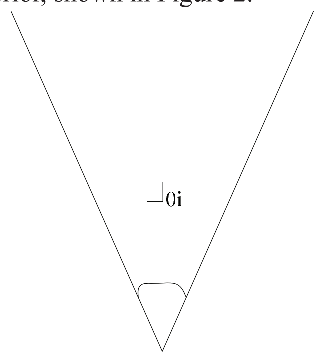

Figure 2 Dynamic Economic Hinterland

B. Symbol

Input parameters are as follow:

V : The number of all ports within the Port group;

$c_i, i = 0,1,\cdots V$: The average transport costs of the hinterland of port i ;

$a_{0i}, i = 1,\cdots V$: The average transport costs between the hub port 0 and spoke port i ;

$A_i, i = 0,1,\cdots V$: The maximum throughput capacity of the port i ;

M_f : The imported goods of unit area generated by all based-land hinterland within the whole region system;

M_g : The exported goods of unit area generated by all based-land hinterland within the whole region system.

Decision variable:

R_i : The radius of hinterland of port i ;

$R_i^{\max}, i = 0,1,\cdots V$: The maximum radius of the hinterland of port i ;

θ_i : The Central angle of hinterland of port i ;

$\theta_i^{\min}, \theta_i^{\max}$, $i = 0,1,\ldots,V$, is the minimum angle and the maximum angle of hinterland of port i ,respectively;

R_{0i} : The radius of the dynamic hinterland of port i and port 0;

$R_{0i}^{\max}, i = 1,\cdots V$: The maximum radius of the dynamic hinterland of port i and port 0;

θ_{0i} : The Central angle of the dynamic hinterland of port i and port 0;

$\theta_{0i}^{\min}, \theta_{0i}^{\max}, i = 1, \cdots, V$ is the minimum angle and the maximum angle of the dynamic hinterland of port i and port 0, respectively.

C. Model

Objective functions

$$\max F = \sum_{i=1}^{V} c_i * (M_f + M_g) * (\tfrac{1}{2} * R_i^2 * \theta_i - \alpha * \tfrac{1}{2} * R_{0i}^2 * \theta_{0i})$$
$$+ \sum_{i=1}^{V} a_{0i} * (M_f + M_g) * (\tfrac{1}{2} * R_i^2 * \theta_i - \alpha * \tfrac{1}{2} * R_{0i}^2 * \theta_{0i}) \quad \text{s.t.}$$
$$+ c_0 * (M_f + M_g) * \tfrac{1}{2} * (R_0^2 * \theta_0 - (1-\alpha) \sum_{i=1}^{V} R_{0i}^2 * \theta_{0i})$$

$$(M_f + M_g) * (\tfrac{1}{2} * R_i^2 * \theta_i - \alpha * \tfrac{1}{2} * R_{0i}^2 * \theta_{0i}) \le A_i,\ i = 1, \ldots, V, \quad (1)$$

$$(M_f + M_g) * \tfrac{1}{2} * (R_0^2 * \theta_0 - (1-\alpha) \sum_{i=1}^{V} R_{0i}^2 * \theta_{0i}) \le A_0 \quad (2)$$

$$0 \le R_i \le R_i^{\max}, i = 0, 1, \cdots V; \quad (3)$$

$$0 \le R_{0i} \le R_{0i}^{\max}, i = 1, \cdots V; \quad (4)$$

$$\theta_i^{\min} \le \theta_i \le \theta_i^{\max},\ i = 0, 1, \ldots, V; \quad (5)$$

$$\theta_{0i}^{\min} \le \theta_{0i} \le \theta_{0i}^{\max}, i = 1, \cdots, V; \quad (6)$$

where α is an adjust parameter. Objective function is to minimize the total transport costs in Hub-and-Spoke logistics transportation system; Constraint (1) and (2) indicate that the volume of freight on the route between two ports can not exceed the total throughput capacity of the ports; Constraint (3)-(6) indicates that the radius and angle of ports are within the limits.

3 Numerical example

In order to validate the model, the paper carried out the following numerical calculation and analysis. Suppose that there are three ports in the region, there may be transport of goods between Hub port and Spoke ports. All the parameters are showed in table 1-5.

$c_i, i = 0, 1, \cdots V$: The average transport costs of hinterland of port i;

TABLE 1 The averege Transportation Costs of the hinterland of port(10000yuan/ton)

	HUB PORT 0	*SPOKE PORT 1*	*SPORE PORT 2*
c_i	0.006	0.002	0.0015

TABLE 2 The averger Transportation Costs between Hub sport and spore sports(10 000yuan/ton)

a_{0i}	*SPOKE PORT 1*	*SPOKE PORT 2*
HUB PORT 0	0.001	0.0015

TABLE 3 The maximum troughput capacity of port(10000ton)

HUB PORT 0	*SPOKE PORT 1*	*SPORE PORT 2*

A_i	320000	143000	215000

TABLE 4 The exported and imported vlumue of unit area of hinterland(1000ton/km2)

M_f	M_g
2	2

TABLE 5 The minimum and maximum value of decision variables

θ_i		θ_{0i}		R_i (km^2)		R_{0i} (km^2)	
min	max	min	max	min	max	min	max
1/6 π	2/3 π	0	2/3 π	0	500	0	300

Because of the objective function of the above model is linear, and some constraints are linear and some are non-linear, they just right meet the demand of fmincon function in Matlab. Set corresponding parameters, optimization results demonstrate that exitflag$>$0, which shows that the process converges to the optimal soultion successfully. The finally optimization result of the model: the minimum transportation cost of the overall system is 29.94 billion yuan; the result is shown in figure 3, where points represent Hub port 0, Spoke port 1 and spoke port 2.

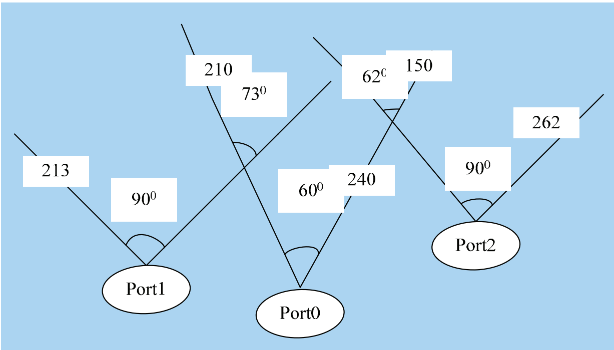

Figure 3 Simple Structure of Hub-and-Spoke Network

4 Conclusion

Based on dynamic hinterland conditions, this paper proposed an optimization idea for port group system and established an optimization model of Hub and Spoke network. Through model analysis of concrete examples and solved by Matlab, it proves that this model has a strong scientific and practical.

Acknowledgements

This research is supported by National Science Foundation of Dalian (No.2009Z081), Fundamental Research Funds for the Central Universities (No.2009QN077) and Scientific Research Foundation for the Returned Overseas Chinese Scholars, State Education Ministry (SRF for ROCS, SEM).

References

[1]. L. J. Zhang, C.H. Hou, G.Q. Hu,.Morden Port Logistics[M].Beijing: China Morden Economics Publishing House, pp. 188-209, 2005.

[2]. J. Q.Yang.Gravity Model for Partitioning Port Hinterlands Based on Fuzzy Comprehensive Evaluation [J]. Journal of Traffic and Transportation Engineering, vol.2,pp.123-126, 2002.

[3]. Y. C. Bai.Research of Hinterland Segmentation Method Based on Attractive Force Model [D]. Beijing Jiaotong University, Beijing, 2008.

[4]. S.S. Fang. The mutual Relations between Ports in Three Different Layers in South China and Their Hinterlands [D].Shanghai: Fudan University, 2004.

[5]. C.X. Wang. Optimization of Hub-and-spoke Based Regional Port Cluster Two Stage Logistics System Network[J].Systems Engineering-Theory & Practice ,vol.9, pp.152-158, 2008.

[6]. W. Lu.Implement of Port Logistics Center[J].Shipping Management,2001,vol.12pp.2-4,2001.

[7]. J.Y. Zhao,L.P. Zhao.Urban Traffic Flow Control Prototype System Based on Multi-agent[J].Journal of Traffic and Transportation Engineering,vol.3,pp.101-105,2003.

[8]. B.C. Wei, Y.H.Wang.Research on Bi-level Progamming Model of Transportation Assignment for Integratation Corridor[J].Logistics Sci-tech,vol.8,pp.62-64,2008.

[9]. X.J. Feng,W.Wang, L.P.Jiang.Optimization Model and Algorithm of Port Cluster System[J].Journal of Traffic and Transportation Engineering,vol.8,pp.77-81,2008.

[10]. Z.J. Guo, N.Wang, H.Huo.Study of Model of Port Planning for Multimodel Container Transportation[J].Journal of Dalian University of Technology,vol.41,pp.586-601, 2001.

[11]. H.Zhen.Optimization of Port Logistics[J].Chinese Port,vol.8, pp.41-43,1999.

[12]. M. Matthew. An Analysis of Port Selection[D]. University of California，Berkeley, 2001.

[13]. B. Hoyle, J. Charlier. Inter-port Competition in Developing Countries:an East African Case Study[J].Journal of Transport Geography,1995,vol.3,pp.87-103,1995.

[14]. Y.Hayuth. Rationalization and Deconcentration of the U.S. Container Port System[J]. The Professionall Geographer, vol.40,pp.279-288,1988.