A Logistics Node Location Algorithm under the Situation of Random Disruption

Jiguang Wang, Jiang Wu, Jifeng Li

***Abstract*— Introduce the disruption factors in the logistics nodes location problem, and the nodes are divided into reliability and unreliability nodes (disruption risk). This paper analyzes the effective emergency alternatives after the disruption of unreliable nodes and take this problem into account in the previous logistics node location research to ensure that the time and cost are least loss in disruption occurs, put forward specific algorithm, and give some examples to verify.**

***Index Terms*— Supply chain design; Facility location; Path planning; Random disruption**

I. INTRODUCTION

Facility Location Problem (FLP) in city planning has a wide range of various forms and important practical significance in many fields such as public service, industry distribution, warehousing, distribution system and living facilities. Especially in the logistics system, node facilities undertakes the functions of scale transport, optimization of inventory control and others, has strategic significance in the process of the whole optimization.

Although a large number of literature study on facility location problem (Drezner, Hamacher, Owen, 2004; Daskin, 1998; Shmoys, Tardos, Aardal, 1997; Li, 2008; Wang, Ren, 2008; Qin, Shi, 2007), but the hypothesis of the classical facility location problem is usually that the facility, all nodes are in the normal operation. Under this assumption, they obtain the best location based on the cost, income, response time and other targets. However, with the rapid change of the market, the uncertainty of actual production, transportation time, arrival time, demand, demand for space distribution and facilities construction costs, transportation costs and other input variable are increases lead to the static, deterministic location model and method do not adapt to the development of research on facility location, node. This uncertainty also makes the supply chain decision problems become more complex.

This paper will study the policy decision of facility location and demand allocation in random disruptions of production facilities situation, to build a more robust supply chain network. In this context, all production facilities are divided into two categories: one category is the reliable facilities, is the key target of investment and management of the supply chain in the process of operation, assumed that such facilities will not be random disruption; another kind is not reliable facility which have random disruption risk.

This paper will describe the facility reliability problem (FRP) though a mixed integer programming model, and solve it by Java programming language.

Manuscript received November 23, 2014.

Jiguang Wang, PhD, is a Lecturer in the School of economics and management, Shanxi University. His research field is industrial engineering. Jiguang Wang is the corresponding author and can be contacted at:

Jiang Wu, MA, is a graduate student in the School of economics and management, Shanxi University. His research field is industrial engineering.

Jingfeng Li, PhD, is a Professor, PhD supervisor in the School of economics and management, Shanxi University. His research field is industrial engineering.

II. THE MODEL OF RELIABILITY PROBLEMS OF SUPPLY CHAIN ESTABLISHMENT

In consideration of the random disruption facilities, the problem of supply chain reliability (FRP) in this chapter extends uncapacitated fixed charge location problem(UFLP).The purpose of the FRP is to minimizes the total fixed cost of facilities and the transportation cost through appropriate planning the reliable operation facilities and the instable facilities which with disruption risk. we assume the $j \in N$ as the facility node, where N is the set of all nodes, including supply chain demand nodes and (optional) facility node. At each node, we can allocation a unreliable facility with Outage probability q_j ($0<q_j<1$) in cost f_j^U or deployment a reliable facility in cost f_j^R, where $f_j^R > f_j^U$ in reality. Consistent with UFLP, in the situation of fully meet all the demand, the supply chain managers to determine the optimal number and location of the two kinds of facilities. Under normal circumstances, the main task of demand nodes i can be completed by any type of node facilities of the initial allocation, and at the same time, the nearest reliable facilities as the backup to prevent the disruption of unreliable facilities in initial allocation.

We use d_{ij} to represent the transportation cost between demand node i to facility node j. So that we can use d_{ij}^P to represent the transportation cost when j as the initial allocation facilities, use d_{ij}^B to represent the transportation cost when j_0 as the backup reliable facilities. We assume $d_{ij}^B > d_{ij}^P$, for taking into account the path extended when established the backup facilities while the supply chain node facilities disruption. Moreover this paper assumes that the demand of each node i is h_i, and the node facilities have sufficient

capacity to meet the node demand $\boldsymbol{h_i}$.
The sets, parameters, and decision variables in FRP are defined as follows:

N= the set of all nodes

h_i = demand of node $\boldsymbol{i}$

f_j^U = the fixed cost for allocation an unreliable facility to node $\boldsymbol{j}$, which exist disruption risk, $\boldsymbol{J \in N}$;

f_j^R = the fixed cost of allocating a reliable facility to node $\boldsymbol{j}$, which does not have disruption risk, $\boldsymbol{J \in N}$;

q_j = disruption probability of unreliable facilities for node $\boldsymbol{j}$

d_{ij}^P = represent the unit transportation cost from demand node $\boldsymbol{i}$ to facility $\boldsymbol{j}$,when the facility $\boldsymbol{j}$ as the initial distribution facilities. $\boldsymbol{i, j \in N}$;

d_{ij}^B = represent the unit transportation cost from demand node i to facility $\boldsymbol{j}$,when the facility $\boldsymbol{j}$ as the backup facilities. $\boldsymbol{i, j \in N}$;

Decision variables

$X_j^U = 1$, represent an unreliable facilities configured in the node $\boldsymbol{j}$; 0 said that has not been deployed in this node;

$X_j^R = 1$, represent a reliable facilities configured in the node $\boldsymbol{j}$; 0 said that has not been deployed in this node;

$Y_{ij}^P = 1$ Means that the demand of node $\boldsymbol{i}$ is initially assigned to node facilities $\boldsymbol{j}$ (reliable or unreliable); 0 said not allocated in the node;

$Y_{ij}^B = 1$, represent the demand of node $\boldsymbol{i}$ has been allocated in a emergency way to the backup reliable infrastructure node $\boldsymbol{j_0}$, after the disruption of the original distribution; 0 means not allocated in the node;

Construct FRP objective function based on the describe of above variables:

$$\min_{X,Y} \sum_{j \in N} f_j^U X_j^U + \sum_{j \in N} f_j^R X_j^R + \sum_{i \in N} \sum_{j \in N} (1-q_j) h_i d_{ij}^P Y_{ij}^P + \sum_{i \in N} \sum_{j \in N} q_j h_i d_{ij_0}^B Y_{ij_0}^B \quad (3.1)$$

s.t.

$$\sum_{j \in N} Y_{ij}^P = 1, \sum_{j \in N} Y_{ij_0}^B = 1, \forall i \in N \quad (3.2)$$

$$Y_{ij}^P \le X_j^R + X_j^U, \quad Y_{ij_0}^B \le X_j^R, \quad \forall i, j \in N \quad (3.3)$$

$$X_j^R + X_j^U \le 1, \quad \forall j \in N \quad (3.4)$$

$$\sum_{j \in N} X_j^R \ge 1 \quad (3.5)$$

$$X_j^U, X_j^R \in \{0,1\}, \quad \forall j \in N \quad (3.6)$$

$$Y_{ij}^P, Y_{ij0}^B, \in \{0,1\}, \quad \forall i, j_0 \in N \quad (3.7)$$

The objective function (3.1) is composed of four parts, the first two are respectively fixed location cost of unreliable and reliable facilities; third said the expected cost of transportation when demand task completed by initial distribution node facilities, the node may be reliable facility or unreliable facility; fourth represents the transport cost after the demand task in the initial distribution node have disruption and completed by the backup reliable facilities.

Constraints (3.2) represent the demand node i should be assigned to a facility node in the initial allocation or to a backup reliable node in a emergency way after the disruption of the unreliable facilities; constraint (3.3) shows that any initial distribution of node i may be allocated to the two types of facilities, but the backup task must be allocated to the reliable facilities; (3.4) showed that only one of the two types of facilities could be deployment in a node; constraints (3.5) showed that at least one node have the reliable facility in all of them. (It means all the facilities are unreliable is impossible). Constraints (3.6) and (3.7) are the integrity constraints.

III. Algorithm for Example

A. Method introduction

This paper give the location algorithm of distribution center based on minimal transportation distance with the Java description language, according to the 3.2 model abstraction, we define array “station” as the total transportation costs to all demand points from any one of the Alternative facilities node. $\boldsymbol{i}$ and $\boldsymbol{j}$ were demand and potential facilities node. Take the method of nested loops to determine the total cost required in the alternative node selected for an arbitrary number and position, and determining the smallest one after compared to the total cost of the alternative scheme.

B. Example analysis

In order to easily understanding, we give an example based on the above program. The design consists of 8 optional nodes (*A*, *B*, *C*, *D*, *E*, *F*, *G*, *H*), and 21 demand points (1~21), distance between each demand point and distribution center are given in Table 1. Fixed cost deployment of reliable and unreliable infrastructure facilities were f_j^R =15,000,000 and f_j^U =10,000,000, the normal unit transportation cost as 1; supply chain disruption probability q= 0.2; the demand for each demand point are set to 10,000.

Table 1. Distance between demand point and distribution center

center / demand	A	B	C	D	E	F	G	H
1	200	300	400	200	500	400	500	200
2	300	400	600	500	200	300	400	600
3	600	600	900	1,000	800	900	1,000	800
4	1,000	1,200	3200	1,500	900	1,200	800	800
5	300	400	600	700	700	500	700	900
6	600	700	1000	1,200	700	800	800	400
7	800	700	500	1,200	1,500	500	1,000	800
8	500	400	800	1,000	900	300	500	700
9	300	400	400	500	800	500	700	900
10	600	600	4,000	2,400	900	1,300	600	1,800
11	1,900	1,700	1,200	900	1,600	1,400	1,000	800
12	800	900	1,000	1,100	700	900	500	500
13	1,000	400	1,400	1,500	1,000	600	800	900
14	500	800	800	100	600	400	700	900
15	400	1,300	1,700	1,600	1,200	900	700	700
16	600	600	1,700	900	700	500	800	900
17	1,400	1,200	600	900	1,200	1,000	900	800
18	500	600	600	1,800	300	800	1,000	900
19	1,500	2,100	2,000	3,400	1,600	1,400	1,200	1,000
20	700	900	700	900	1,000	400	800	1,500
21	1,000	900	1,500	700	1,600	400	1,200	700

According to the above data with the program, the system will automatically calculate the number and locations of the distribution points in this region based on the minimum cost, the results are showed in Table 2.

Table 2. Operation result

Distribution center selected	The corresponding demand point	Expenditure
A	1,2,5,3,9,10,15,18	240
F	8,14,16,7,13,20,21	232.5
H	19,4,6,11,12,17	322.5

Based on the results above, we selected node A, F, H, for three investment center, corresponding to the 21 demand points.

C. Determine the types of facilities

After the investment center is selected, we should consider the investment scheme, we have two kinds of nodes: reliability nodes and unreliable nodes with the outage probability 0.2.In case of the risk of the disruption occurs in unreliable nodes ,we must to seek minimum cost reliable infrastructure as an alternative scheme , so a reliable infrastructure must to be included. The alternative expenses of these three nodes are showed in Table 3. The decisions of the dynamic logistics network configuration include deciding whether to open or close the logistics centers at each potential depot and the quantities of coal that are to be shipped in the transportation links at each time period.

Table 3. The node replacement cost

region / node	A (1,2,5,3,9,10,15,1)	F (8,14,16,7,13,20,21)	H (19,4,6,11,12,17)
A	24,000,000	62,000,000	88,000,000
F	60,000,000	23,250,000	67,000,000
H	94,000,000	71,000,000	32,250,000

According to the amount of the reliable facilities, we will divided the project into three categories, cost calculation in Table 4

- In the ***A, F, H***, if the three are reliable facilities, the total cost is 15,000,000*3+24,000,000+23,250,000+32,250,000=124,500,000
- In the ***A, F, H*** , if ***A*** is not a reliable infrastructure nodes, the total cost must to add the replacement cost of F to A after the disruption is occurred and multiplied the outage probability: 15,000,000*2+10,000,000+23,250,000+32,250,000+24,000,000*0.8+ 60,000,000*0.2 = 126,700,000.
- In the ***A, F, H*** three node, if ***A, F*** is not reliable infrastructure node, the total cost shown in figure 1.

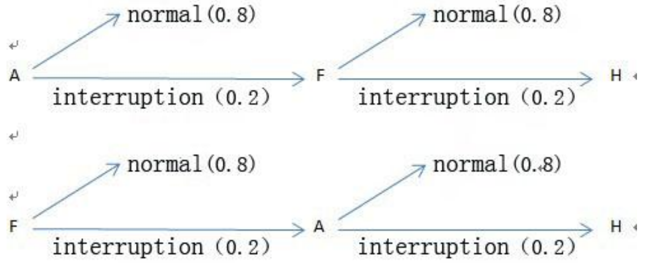

Fig.1 Solution process of the total cost

Table 4. The total cost

A	F	H	Total cost
reliable	reliable	reliable	124,500,000
unreliable	reliable	reliable	126,700,000
reliable	unreliable	reliable	121,300,000
reliable	reliable	unreliable	128,600,000
unreliable	unreliable	reliable	138,400,000
reliable	unreliable	unreliable	122,700,000
unreliable	reliable	unreliable	125,600,000

Through the above results, we have the minimum cost investment plan: select the *F* point is not reliable facilities, *A* point and *H* point for reliable facilities.

Similarly, we can obtained the investment plan again when outage probability *q*=0.05 according to the above steps. The result had shown in Table 5 and Figure 2.So that we get the investment projects in different outage probability.

Table 5. The investment distribution in different disruption probability.

Outage probability	Reliable facilities	Unreliable facilities	The cost of facilities	Transportation costs	The total cost
q=0.2	2	1	40,000,000	81,300,000	121,300,000
q=0.01	1	2	35,000,000	82,100,000	117,100,000

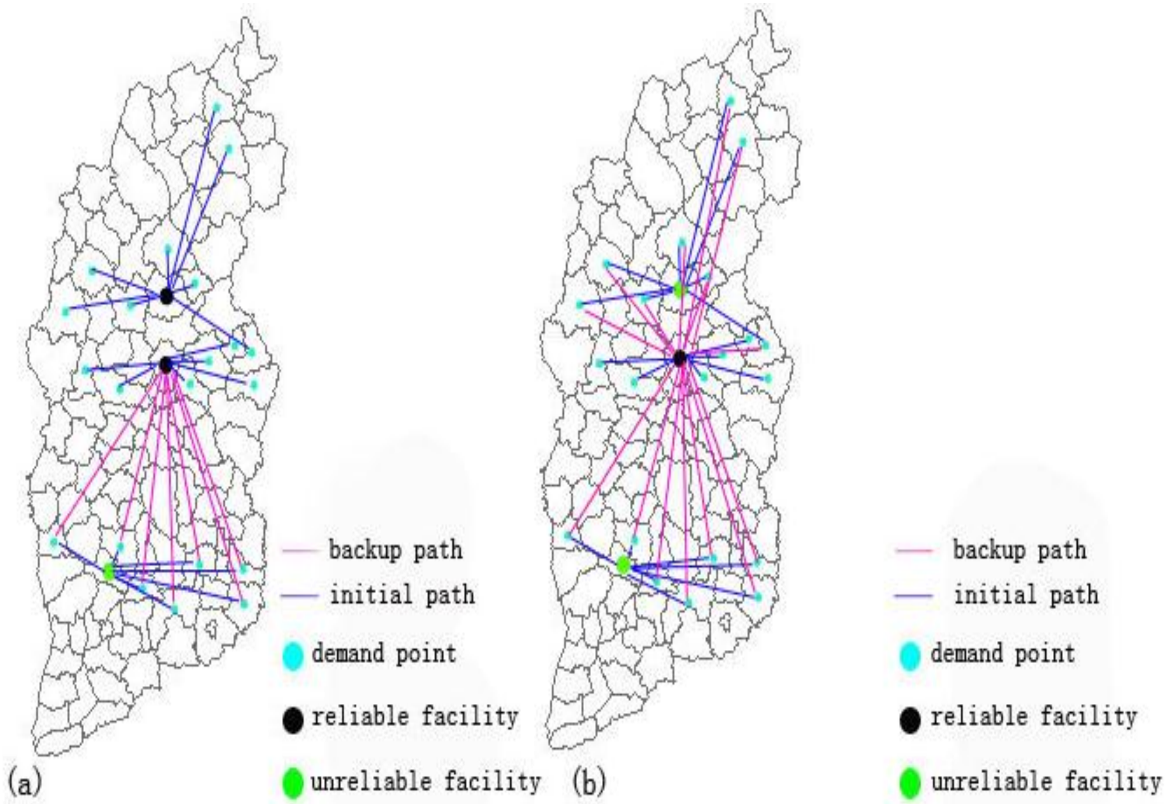

Fig.2(a) The Distribution map when q=0.2,（b）The Distribution map when q=0.05

IV. CONCLUSIONS AND FUTURE WORK

This paper studies the facility reliability problem (FRP) in the random disruption situation by constructing a mixed integer programming model which solved it based on the Java programming language. We get the optimal location of unreliable and reliable facilities. The algorithm has obvious advantages in solving large-scale problems.

However, the disadvantages of this model are also obvious. First of all, in order to simplify the research, model does not consider the node capacity problem. Although no capacity constraints model provides a valuable reference to the solution of the model, but it will more perfect if the capacity of the node facilities are taken into account. Secondly, model assumes that a node facility only has two states: normal and disruption, not considering the local disruption, but the situation of local disruption may be more close to the reality. In addition, there are some factors are also worthy of further study such as the rules of set up backup facilities. Finally, the assumption of the outage probability in supply chain model should be further expanded: in the model of this chapter, the outage probability of each node of in supply chain is independent, but in fact, the outage probability of every node in supply chain may also be associated. Thus, it will make us to construct a more robust supply chain network to resist a higher risk situation.

ACKNOWLEDGMENT

The authors would like to thank the editor and anonymous referees for their input and direction, which substantially improved this paper.

REFERENCES

[1] Daskin, M. S. 2011. Network and discrete location: models, algorithms, and applications. John Wiley & Sons.
[2] Drezner, Z. 1995. Facility location: a survey of applications and methods. Springer Verlag.
[3] Erol, I., & Ferrell Jr, W. G. 2004. A methodology to support decision making across the supply chain of an industrial distributor. International Journal of Production Economics 89(2): 119-129.
[4] Fahimnia, B., Farahani, R. Z., Marian, R., & Luong, L. 2012. A review and critique on integrated production–distribution planning models and techniques. Journal of Manufacturing Systems 85(2): 105-119.
[5] Farahani, R. Z., & Hekmatfar, M. (Eds.). 2009. Facility location: concepts, models, algorithms and case studies. Springer 23(3): 102-129
[6] Farahani, R. Z., SteadieSeifi, M., & Asgari, N. 2010. Multiple criteria facility location problems: A survey. Applied Mathematical Modelling 34(7): 1689-1709.
[7] Fleischmann, M., Krikke, H. R., Dekker, R., & Flapper, S. D. P. 2000. A characterisation of logistics networks for product recovery. Omega 28(6): 653-666.
[8] Hervet, C., Faye, A., Costa, M. C., Chardy, M., & Francfort, S. 2013. Solving the Two-Stage Robust FTTH network design Problem under Demand Uncertainty. Electronic Notes in Discrete Mathematics 41: 335-342.
[9] Kannan, D., Khodaverdi, R., Olfat, L., Jafarian, A., & Diabat, A. 2013. Integrated fuzzy multi criteria decision making method and multi-objective programming approach for supplier selection and order allocation in a green supply chain. Journal of Cleaner Production 54(2): 222-141
[10] Klose, A., & Drexl, A. 2005. Facility location models for distribution system design. European Journal of Operational Research162(1): 4-29.
[11] Lee, D. H., & Dong, M. 2009. Dynamic network design for reverse logistics operations under uncertainty. Transportation Research Part E: Logistics and Transportation Review 45(1): 61-71.
[12] Li, X. 2013. An integrated modeling framework for design of logistics networks with expedited shipment services. Transportation Research Part E: Logistics and Transportation Review 56: 46-63.
[13] Li, X., & Ouyang, Y. 2012. Reliable traffic sensor deployment under probabilistic disruptions and generalized surveillance effectiveness measures. Operations Research 60(5): 1183-1198.
[14] Lin, L., Gen, M., & Wang, X. 2009. Integrated multistage logistics network design by using hybrid evolutionary algorithm. Computers & Industrial Engineering 56(3): 854-873.
[15] Listeş, O., & Dekker, R. 2005. A stochastic approach to a case study for product recovery network design. European Journal of Operational Research 160(1): 268-287.
[16] Melo, M. T., Nickel, S., & Saldanha-Da-Gama, F. 2009. Facility location and supply chain management–A review. European Journal of Operational Research 196(2): 401-412.
[17] Minner, S. 2003. Multiple-supplier inventory models in supply chain management: A review. International Journal of Production Economics 81: 265-279.
[18] Ramezani, M., Bashiri, M., & Tavakkoli-Moghaddam, R. 2013. A new multi-objective stochastic model for a forward/reverse logistic network design with responsiveness and quality level. Applied Mathematical Modelling 37(1):

Jiguang Wang [i], PhD, is a Lecturer in the School of economics and management, Shanxi University. His research field is industrial engineering. Jiguang Wang is the corresponding author and can be contacted at:

Jiang Wu, MA, is a graduate student in the School of economics and management, Shanxi University. His research field is industrial engineering.

Jingfeng Li, PhD, is a Professor, PhD supervisor in the School of economics and management, Shanxi University. His research field is industrial engineering.

(Affiliation): School of economics and management, Shanxi University, Taiyuan, China
No.92, Wucheng Road, Taiyuan 030006, China

[i] The authors would like to thank the editor and anonymous referees for their input and direction, which substantially improved this paper. This work was partly supported by the Program for the Philosophy and Social Sciences Research of Higher Learning Institutions of Shanxi (PSSR) (2014204).