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Robust Optimization on the Fourth Party Logistics Network with Purchase – Return Reverse Logistics

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Abstract. One single-period many products 4PL network location model which synthetically taking the manufactory, centralized return centre, consumption area/initial return point, repair processing centre, distribution centre, and disposal centre into account,is constructed in this paper. The objective is to minimize the total cost. In the uncertain condition of recovery rate, sales and return rate, the model is contructed with the method of robust optimization. The result of the examples verified the robustness of the model.

Introduction

The concept of fourth party logistics(4PL) was proposed by Accenture Consulting in 1998. It is given in Strategic Supply Chain Alignment:'A 4PL is an integrator that assembles the resources,capabilities, and technology of its own organization and other organizations to design, build and run comprehensive supply chain solutions'[1].At present,the papers of 4PL path problems are based on multigraph to build models and focus on improving algorithm[2-6]. In this paper, the robust optimization is applied to 4PL.This paper will try to solve the problem is: to the minimum total cost as the goal, centralized return centre, repair processing centre and distribution centre in purchase-return the fourth party logistics network and then determine the optimal transport routes and numbers between the facilities, finally a numerical example is validated.

4PL network model with purchase-return reverse logistics

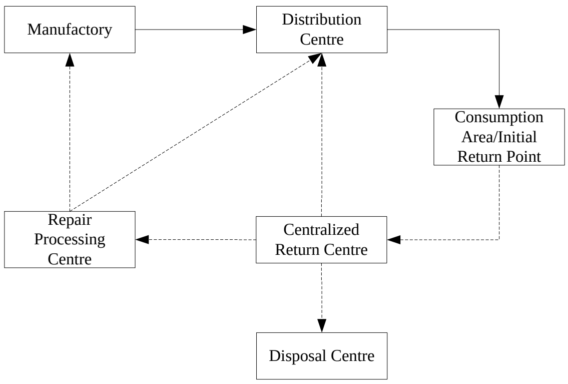

Fig. 1 Purchase-return 4PL network

Based on the references[],we construct a purchase-return 4PL network structure as shown in Fig. 1.It includes manufactory, centralized return centre, consumption area/initial return point, repair processing centre, distribution centre, and disposal center. All returned merchandise first ship from consuming area / initial return point to centralized return center, where going detection and classification: The damaged returns in the process of loading and unloading, transport and due to production and warranty period are shipped to repair processing centre, after dealing with necessary repair and restore its function to distribution center for sale again, while without restoring its function and damaged seriously goods shipped to manufactory for producing to restore its function again, then again shipped to distribution centers to wait for re-sale; due to reasons such as transportation, packaging, loading and unloading , goods which are sent by mistake are sent directly to distribution center for re-sale, at the same time to be replaced by the right goods, and re-transport to customers; due to reasons such as customers' personal preferences not defective "defects" are directly shipped to distribution centers, through simple operations such as cleaning ,maintenance and repackaging, continue to be saled in the market; while goods in centralized return centre which do not have function should be shipped to disposal center for landfill disposal. In order to facilitate analysis, we give the assumption and instructions are same as references[6,7] and appendix.

Then the model is as follows:

$$R_s=\sum_{v=1}^{V}F_v\cdot y_v/T_v+\sum_{i=1}^{I}F_i\cdot y_i/T_i+\sum_{j=1}^{J}F_j\cdot y_j/T_j+\sum_{l=1}^{L}\sum_{i=1}^{I}\sum_{e=1}^{E}X_{slie}\cdot C_{lie}\cdot d_{li}+$$
$$\sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{e=1}^{E}X_{sije}\cdot C_{ije}\cdot d_{ij}+\sum_{i=1}^{I}\sum_{v=1}^{V}\sum_{e=1}^{E}X_{sive}\cdot C_{ive}\cdot d_{iv}+\sum_{i=1}^{I}\sum_{k=1}^{K}\sum_{e=1}^{E}X_{sike}\cdot C_{ike}\cdot d_{ik}+$$
$$\sum_{j=1}^{J}\sum_{v=1}^{V}\sum_{e=1}^{E}X_{sjve}\cdot C_{jve}\cdot d_{jv}+\sum_{j=1}^{J}\sum_{m=1}^{M}\sum_{e=1}^{E}X_{sjme}\cdot C_{jme}\cdot d_{jm}+\sum_{m=1}^{M}\sum_{v=1}^{V}\sum_{e=1}^{E}X_{smve}\cdot C_{mve}\cdot d_{mv}+$$
$$\sum_{v=1}^{V}\sum_{l=1}^{L}\sum_{e=1}^{E}X_{svle}\cdot C_{vle}\cdot d_{vl}+\sum_{v=1}^{V}\sum_{l=1}^{L}\sum_{e=1}^{E}X_{svle}\cdot C_{ve}+\sum_{l=1}^{L}\sum_{i=1}^{I}\sum_{e=1}^{E}X_{slie}\cdot C_{ie}+\sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{e=1}^{E}X_{sije}\cdot C_{je}+$$
$$\sum_{i=1}^{I}\sum_{k=1}^{K}\sum_{e=1}^{E}X_{sike}\cdot C_{ke}+\sum_{l=1}^{L}\sum_{i=1}^{I}\sum_{e=1}^{E}X_{slie}\cdot C_{le}-\sum_{j=1}^{J}\sum_{m=1}^{M}\sum_{e=1}^{E}X_{sjme}\cdot CSP_{me}-\sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{e=1}^{E}X_{sije}\cdot CSP_{je}$$

The objective function:

$$\min\left\{\max_{s\in S}\left(R_s-O_s^*\right)\right\}$$

Constraints:

$$\sum_{i=1}^{I}X_{slie}=D_{le}\cdot\alpha_{se}\quad,\sum_{l=1}^{L}X_{slie}=\sum_{j=1}^{J}X_{sije}+\sum_{v=1}^{V}X_{sive}+\sum_{k=1}^{K}X_{sike}\ ,\sum_{i=1}^{I}X_{sije}=\sum_{m=1}^{M}X_{sjme}+\sum_{v=1}^{V}X_{sjve}\ ,$$
$$\sum_{j=1}^{J}X_{sjme}=\sum_{v=1}^{V}X_{smve}\ ,\sum_{l=1}^{L}X_{svle}=\sum_{m=1}^{M}X_{smve}+\sum_{j=1}^{J}X_{sjve}\ ,\sum_{j=1}^{J}X_{sije}=\left(\beta_e+\gamma_e\right)\cdot\sum_{l=1}^{I}X_{slie}\ ,$$
$$\sum_{v=1}^{V}X_{sive}=\left(\mu_e+\eta_e\right)\cdot\sum_{l=1}^{L}X_{slie},\sum_{v=1}^{V}X_{sjve}=\theta_e\cdot\sum_{i=1}^{I}X_{sije},\forall s,i,j,v,l,e \tag{1}$$

$$\sum_{l=1}^{L}X_{slie}\le U_{ie}\cdot y_i\quad,\sum_{i=1}^{I}X_{sije}\le U_{je}\cdot y_j\ ,\sum_{l=1}^{L}X_{svle}\le U_{ve}\cdot y_v\quad,\quad\forall s,i,j,v,e \tag{2}$$

$$X_{slie}\le w\cdot y_i\quad X_{svle}\le w\cdot y_v\quad,,X_{sive}\le w\cdot y_v\ ,X_{sjve}\le w\cdot y_v\ ,X_{smve}\le w\cdot y_v\quad,X_{sjve}\le w\cdot y_j$$
$$X_{sjme}\le w\cdot y_j\ ,X_{sije}\le w\cdot y_j\ ,X_{sike}\le w\cdot y_i\ ,X_{sive}\le w\cdot y_i,X_{sije}\le w\cdot y_i\qquad\forall s,i,j,k,l,m,v,e \tag{3}$$

$$X_{slie},X_{sije},X_{sive},X_{sike},X_{sjme},X_{sjve},X_{smve},X_{svle}\qquad\forall s,l,i,j,k,m,v,e \tag{4}$$

Where,constraints（1）show logistics conservation; constraints（2）say the maximum processing capacity of the facilities;constraints（3）say that only when the facilities are selected to have associated with traffic; w represents infinity; constraints （4） limit the range of decision variables.

Numerical examples

Table 1 The relevant data of consumption area/initial return point

Consumption Area/Initial Return Point L_l	Position Coordinates	disposal cost per unit of product C_{le} （Yuan/Ton）	Sales D_{le} （Ton）
L_1	（185,65）	75/70	[800,1200]/[700,1250]
L_2	（125,80）	60/55	[850,1200]/[900,1200]
L_3	（148,85）	48/42	[700,900]/[800,900]
L_4	（110,70）	80/76	[1100,1300]/[1200,1500]

To carry out effective sales - returns management, a large home appliance enterprise uses the above robust model, and build a high efficient and reasonable purchase - return fourth party logistics network. In this paper, the purchase - return situations of two kinds of products are analyzed. The location, disposal cost per unit of product and sales of consumption area/initial return point are shown in Table 1.

In order to facilitate analysis, other return behaviors are not considered (such as seasonal returns, cleaning inventory of retailers and product recall returns of manufacturers, etc.). According to the market situation, the return rates of major home appliances usually around 4.5%, and the return rate of the components in the product life cycle may be much higher (10% - 25%). This numerical example assumes that return rate of product 1 is divided into 0.025 and 0.04 two kinds of cases, return rate of product 2 is divided into 0.03 and 0.04 two kinds of cases. These form 4 different scenarios. The specific combination of scenarios are shown in Table 2.

Table 2 combination of scenarios under uncertain

scenario S	return rate of product 1	return rate of product 2
1	0.025	0.03
2	0.025	0.04
3	0.04	0.03
4	0.04	0.04

The layout planning of centralized return centers, distribution centers and repair processing centers is the core content of the purchase - return fourth party logistics network.Determination of the alternative locations is not arbitrary, and we must follow the strategic principles such as adaptability, coordination, economy to choose appropriate addresses as candidate sites. By the comprehensive evaluation, I_1, I_2, I_3 and I_4 are selected as alternative locations of newly-bulit centralized return centers; V_1, V_2 and V_3 are selected as alternative locations of newly-bulit distribution centres; while considering the factors such as technology and resources, J_1, J_2 and J_3 are selected as alternative locations of newly-bulit repair disposal centres.All of these are shown in Table 3.

Table 3 The relevant data of centralized return centre, repair processing centre and distribution centre

alternative facilities number I_i、V_v、J_j	alternative facilities position coordinates	fixed cost of new facilities F_i、F_v、F_j（10^4*yuan）	disposal cost per unit of product e C_{ie}、C_{ve}、C_{je}（yuan/ton）	the maximum processing capacity U_{ie}、U_{ve}、U_{je}（ton）
I_1	(100,40)	25.5	100/110	500/550
I_2	(120,70)	30	120/110	500/540
I_3	(165,75)	25	150/135	500/491
I_4	(125,90)	20	125/110	500/470
V_1	(125,115)	15	80/75	700/700
V_2	(145,130)	15	75/70	710/700
V_3	(160,100)	18	82/80	700/700
J_1	（120,100）	30	150/145	400/350
J_2	（150,105）	38.8	140/142	400/350
J_3	（140,120）	25	150/140	400/350

Table 4 The relevant data of known manufactory

manufactory number M_m	position coordinates	purchase costs per unit saved by manufactories for using recycled product e per unit CSP_{me}（yuan/ton）
M_1	（125,130）	100/150
M_2	（155,125）	120/160

Purchase costs per unit saved by repair processing centres for using re-repaired product e per unit of alternative repair disposal centres are 110,120,130 and 145,150,160. Known position coordinates and purchase costs per unit saved by manufactories for using recycled product e per unit are shown in Table 4.Position coordinates and disposal cost per unit of product e of known disposal centers are shown in Table 5.

Table 5 The relevant data of known disposal centre

number of disposal centers K_k	position coordinates	disposal cost per unit of product e C_{ke}（yuan/ton）
K_1	（130,75）	80/90
K_2	（155,75）	90/105

Due to different reasons of return, there is a certain difference about various probabilities of returns, and specific parameters are shown in table 6.

Table 6 various happening probabilities of returns

parameter	β_e	γ_e	μ_e	η_e	θ_e
	0.15/0.1	0.1/0.11	0.05/0.04	0.65/0.73	0.5/0.45

In this numerical example, flexible and fast road return transportation is chosen,and calculation of shipping costs per unit of product e between facilities uses the relationship which unit transportation cost is proportional to the distance between facilities to measure. Unit transportation costs of two kinds of products are $C_{ij1} = 0.8 * d_{ij}$ and $C_{ij2} = 0.7 * d_{ij}$, and transportation distance is used Euclidean distance to express,that is $d_{ij} = \sqrt{(x_j - x_i)^2 + (y_j - y_i)^2}$. The distances between facilities are shown in table 7.

Table 7 distance between the facilities（km）

facilities number	I_1	I_2	I_3	I_4	M_1	M_2	V_1	V_2	V_3
L_1	88.60	65.19	22.36	65	—	—	78.10	76.32	43.01
L_2	65	11.18	60.21	10	—	—	35	53.85	40.31
L_3	65.80	31.76	19.72	23.54	—	—	37.80	45.10	19.21
L_4	100	10	55.23	25	—	—	47.43	69.46	58.31
J_1	20	30	51.48	15	30.41	43.01	15.81	39.05	40
J_2	82.01	46.10	33.54	27.39	35.36	20.62	26.93	25.50	11.18
J_3	89.44	53.85	51.48	32.02	18.03	15.81	15.81	11.18	28.28
K_1	46.10	15	35	15.81	—	—	—	—	—
K_2	65.19	35.36	10	33.54	—	—	—	—	—
V_1	79.06	45.28	56.57	25	15	31.62	—	—	—
V_2	100.62	65	58.52	44.72	20	11.18	—	—	—
V_3	84.85	50	25.50	36.40	46.10	25.50	—	—	—

Table 8 comparison of O*s and Rs

scenario s	R_s（yuan）	O_s^*（yuan）	$(R_s - O_s^*)/O_s^*$ (‰)
1	350832.5	348729.5	5.99
2	404453.5	402338.2	5.23
3	439674.2	428046.2	5.54
4	493295.2	490389.7	5.89

To help the enterprise to find the optimal solution, we use lingo 10.0 software to solve the model in the paper. The optimal value of objective function is $z^* = 11628$. Distribution centers are opened in 1,3 alternative location; centralized return centers are opened in 3,4 alternative location; repair processing centers are opened in 1 alternative location. In various scenarios, the amount of the optimal path and logistics data among the various facilities have nearly as many as a thousand, so this will not be listed. But, to illustrate robustness of constructed the fourth party logistics network model in sales and return rate in uncertainty, I have given the data of Table 8 . Table 8 shows comparison of Rs obtained with robust optimization in various scenarios and O*s under centain. We can see that the cost with robust optimization in various scenarios are generally higher than the cost in corresponding scenarios under certain, but deviation rate is within 6‰ in all scenarios. Because the fourth party logistics robust optimization model consider uncertainties in the worst case,it leads to the change of location and path of the fourth logistics netword. The results show that robust optimization method has been ideally control uncertainty of sales and return rate to make the purchase-return fourth party logistics network has better robustness.

Conclusions

As the e-commerce has become increasingly mature, returns management in the fourth party logistics has become an important problem to be solved in the consumer goods market, optimizing and designing purchase - return fourth party logistics network have very important economic significance. By building high-tech electronics purchase - return fourth party logistics location robust model， we use interval to describe uncertainty of sales and use unknown probability discrete scenarios to describe uncertainty of return rate, then we combine with a numerical example using the combination of interval analysis and scenario analysis method for the optimization of the model and obtain the optimum location strategy, path and logistics quantity. The numerical results demonstrate the robustness of the model and its solution, and have certain theoretical and practical value, and provide guidance for study of purchase - return fourth party logistics network optimization of high-tech electronic product.

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