Journal of Applied Sciences

ISSN 1812-5654

Journal of Applied Sciences 13 (17): 3533-3537, 2013
ISSN 1812-5654 / DOI: 10.3923/jas.2013.3533.3537

Study of Dairy Logistics Distribution System Based on Hybrid Genetic Algorithm

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Abstract: This study designs and optimizes a multi-level dairy logistics distribution system based on hybrid genetic algorithm to satisfy the distribution in large area. Firstly a Logistics center is built near the factory and a distribution center is built near the customer. And an optimization model of tshe dairy logistics distribution system is established by considering the reliability and the cost of the distribution service level. Then the hybrid genetic algorithm is proposed according to the specialty of the optimization model. Finally, a numerical example is given, the results of a numerical example show that the given algorithm is valid for the large-scale logistics network optimization model.

Key words: Distribution system, hybrid genetic algorithm, logistics center

INTRODUCTION

The logistics and distribution network planning is a basic problem in supply chain management research. Enterprises do their own logistics and distribution network planning in order to improve their logistics and distribution services and meet customer demands better. The enterprise's feature for the profit determines that enterprises will inevitably consider costs as much as possible when they do their own logistics and distribution network planning, including logistics facilities construction and operating costs, product transport and distribution costs, inventory costs, etc., the logistics and distribution network planning is made up of such steps: Market demand analysis, logistics facilities location, logistics facilities capacity arrangements, replenishment policy determines, etc. But market demands are uncertain usually and the best logistics and distribution network in one period may not be optimal in the next period. In addition, as a complex system, the logistics and distribution network may occur partly network disruptions at anytime due to some factors.

Li *et al.* (2012) selected a large-scale E-commerce enterprise in China called GD as the case study and established a model based on the lowest starting and operating costs of the time windows. This model can optimize the GD distribution networks of Shanghai. To deal with the disruptions caused by the customer time window changes in the logistics distribution, the disruption model for this problem was set up (Chen and Ju, 2011). Based on this model, a novel genetic algorithm was designed to solve this problem. The strategic mode of logistics distribution was designed based on SWOT analysis theory (Li *et al.*, 2002). The planning of system architecture, including topical structure, layout of logistics distribution center and information infrastructure, was preliminarily discussed. The key design factors of logistics distribution network operational mode were analyzed. A case study from the design of a practical tobacco marketing logistics distribution network was given to show the design process of logistics distribution network. In order to solve the weakness of ant algorithm in large-scale optimization of logistics distribution network and make use of the practicability in area search of dynamic sweep and the superiority in local optimization of ant algorithm, Li and Zhang *et al.* (2006) presented a hybrid algorithm which was the combination of dynamic sweep and ant algorithm and made some experimental computations. The computational results demonstrated that the hybrid algorithm can effectively solve logistics distribution problem.

In order to meet the demand of lower logistics cost and higher quality of service, Yu (2011) presented a win-win logistics distribution network optimization method for the salt industry based on the service radius. The algorithm used the ant radius of clustering algorithm to establish flocking logistics network service and then completed the optimization of the distribution network based on the model of the radius of selecting optimal distribution center model of distribution network. Liu *et al.* (2012) focused on the tie-in-sale characteristic of fast fashion product in the degenerating period of e-commerce retailing. A non-liner mixed integer programming model for multi-product assembling and

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order taken by customer was proposed to maximize the profit of logistics distribution network for fast fashion product. By introducing the assembling parameter and the study of assembling solution, the integer optimization can be realized in different assembling rate. In order to further raise the work efficiency of logistics distribution network, a distribution optimization model in a single distribution center was established for achieving the shortest total distribution distance (Yang, 2010). And meanwhile, a mixed strategy on the basis of branch and bound algorithm was also proposed. This strategy can effectively avoid the instability of intelligent heuristic algorithm and the exponent explosion of traditional optimization algorithm. To mitigate cost burden resulting from the forthcoming carbon emission tax to the urban cold chain distribution activities, an extended distribution network model for carbon tax-constrained capacitated cold chain logistics was developed (Yang *et al*., 2012).

In this study, for the dairy distribution, the customer demand is large and widespread, so reasonable multi-stage distribution network should be established. Firstly, the area near the factory where enormous quantities are dealt with is defined as logistics center. The logistics center brings scale economic benefit into full running and the total cost of supply chain is reduced as well as the cost of company. Secondly, according to customer's location, middle or small logistics points should be established in right area and this point is defined as distribution center, the goods from artery transportation are transported to next step transportation with right manner, until they are delivered to ultimate customer, so that the profit and the efficiency of the logistics can be improved greatly. The effective distribution network of dairy is shown in Fig. 1.

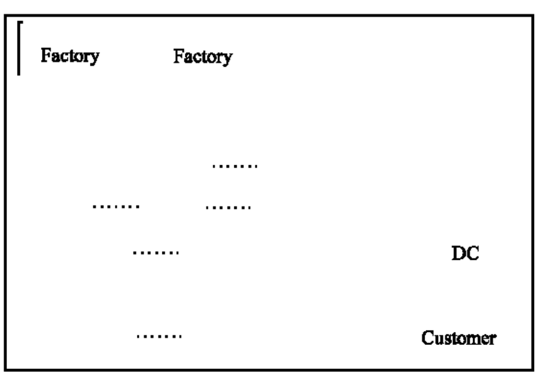

Fig. 1: Distribution network of dairy industry

RELIABILITY OF DISTRIBUTION NETWORK AND ITS CALCULATION

There are different definitions of the reliability in different field. "Logistics system engineering" defines the reliability as: The ability to achieve regulated function on regulated condition within regulated time. To the distribution system, the system reliability is the ability to accomplish distribution action on regulated condition within regulated time, expressed by accomplishment probability, which is regarded as the estimation of distribution center system service level.

This study researches on the dairy distribution. Because the dairy products are short-life span products and time is a crucial element, the distribution should meet customer's needs in time to improve the distribution service, then the reliability is most important to the dairy distribution network. The reliability of the distribution network is the result of mutual effect of many logistics action units in distribution center and logistics center. This paper assumes that the reliability of all the other logistics units (such as picking up goods, collecting goods, assigning goods and so on) is 1 without delivery, so system reliability is just measured by delivery reliability. Exactly, the reliability is probability of the delivery delivered to destination within the regulated time which customer required. According to the fact, the reliability is divided into two: The reliability of logistics center and the reliability of distribution center. The former is related to geography condition and transportation condition. The latter is related to delivery lead time (exactly the interval from receiving order to sending goods to customer), which can be expressed as follows:

$$\begin{aligned} R_{ij} &= P(T_{ij} \le t_j) = P\left|\frac{d_{ij}}{v_{ij}} \le t_j\right| \\ &= P\left|V_{ij} \ge \frac{d_{ij}}{t_j}\right| = 1 - F_{vij}\left|\frac{d_{ij}}{t_j}\right| \end{aligned} \quad (1)$$

$$R_{jk} = P(LT_{jk} \le t_k) = F_{LTjk}(t_k) \quad (2)$$

In Eq. 1 and 2, the meanings of the symbols are shown as follows:

- R_{ij} : Reliability of the delivery from logistics center i to distribution center j
- T_{ij} : Time of products transported from logistics center i to distribution centerj
- t_j : Time limit of distribution center j requested
- d_{ij} : The distance from logistics center i to distribution center j

v_{ij} : The speed of the vehicle from logistics center i to distribution center j, which is related to the statistical rule, the capability of the vehicle, road situation, traffic situation, driving level and so on and it is obeyed to normal school

F_{vij} (.) : Cumulative distribution function of the vehicle speed from logistics center i to distribution center j

R_{jk} : The reliability of the delivery from distribution center i to customer j

LT_{jk} : Lead time of distribution center delivery, which is obeyed to normal school

t_k : Time limit of customer j requested

Based on above single reliability of one logistics center or one distribution center services for one customer, the system reliability in an area of more logistics centers or more distribution centers can be expressed respectively as follows:

$$R_{sys}^{(1)} = \frac{\sum_{i \in M}\sum_{j \in N} f_{ij} R_{ij}}{\sum_{j \in N} f_{ij}} = \frac{\sum_{i \in M}\sum_{j \in N} f_{ij}[1 - F_{vij} | \frac{d_{ij}}{t_j} |]}{\sum_{j \in N} f_{ij}} \quad (3)$$

$$R_{sys}^{(2)} = \frac{\sum_{j \in N}\sum_{k \in K} f_{jk} R_{jk}}{\sum_{k \in K} f_{jk}} = \frac{\sum_{j \in N}\sum_{k \in K} f_{jk} F_{LTjk}(t_k)}{\sum_{k \in K} f_{jk}} \quad (4)$$

where, $R_{sys}^{(1)}$ is defined as the reliability of logistics center, $R_{sys}^{(2)}$ is defined as the reliability of distribution center, f_{ij} is defined as the flow quantity from logistics center to distribution center, f_{jk} is defined as the flow quantity from distribution center to demand point.

OPTIMAL MODEL OF DAIRY DISTRIBUTION NETWORK

For logistics distribution network, the top factory location and the finial customer at the bottom are fixed, so the design of distribution network is the multi-location selection problem for the middle point, that is to say, which is to select optimal location from candidate points of the logistics center and distribution center according to different constraint. The objective is to minimize the total cost of the distribution network on the condition that customer's needs are met greatly.

Assumption condition: There are a number of manufacturing units, which produce certain dairy products (e.g., pasteurized milk, ice cream and yogurt) and operate the market in a particular area. This market requires a specific quantity of this product within a determined time period while in the existing situation the market covers its needs to the greatest degree. There are a set of candidate distribution center nodes, which are cooperated by themselves and some of these are chosen to build distribution center which seeks the best location and the aim is to reduce total distribution cost, as well as to meet the customer's needs within restricted time.

In this study, there are some assumptions as follows:

- Customer demand is calculated by area
- New distribution centers are established only in the candidate points
- Assume that the distribution center can cover the customer's needs to the greatest degree and the capacity of distribution center will not be considered
- One customer is serviced by one distribution center and only one
- The loss in warehouse and storage cost are not considered in system total cost and we only consider the fixed building cost, distribution cost and the cost resulted from the delay delivery

Model establishment: We assume that there is one factory which produces many kinds of products and locating logistics center is near it and then the transportation from factory to logistics center will not be influenced, so the cost of distribution network mainly includes the construction costs of LC and DC, the transportation cost from LC to DC, the distribution cost from distribution center to demand point, disposal costs in LC and DC and the cost resulted from delay delivery.

Define following variables: $V_{(1)}^{i}$ is defined as the construction cost of LC I; $V_{(2)}^{i}$ is defined as the construction cost of distribution center j; $C_{(1)}^{ij}$ is defined as the unit cost of products transported from logistics center i to distribution center j; $C_{(2)}^{jk}$ is defined as the unit cost of products distributed from distribution center j to demand point k; $\varphi_{(1)}^{i}$ and $\varphi_{(2)}^{i}$ are the disposition cost of LC and DC, respectively. S is defined as the number of the possible LC location of the candidate nodes; T is defined as the number of the possible DC location of the candidate nodes.

Mathematical models are established as follows:

$$\begin{aligned} MIN = & \sum_{i=1}^{m} X_i V_{(1)}^{i} + \sum_{j=1}^{n} Y_j V_{(2)}^{j} + \sum_{i=1}^{m}\sum_{j=1}^{n} f_{ij} C_{(1)}^{ij} \\ & + \sum_{j=1}^{n}\sum_{k=1}^{K} f_{ik} C_{(2)}^{jk} + \varphi_{(1)}^{i} f_{ij} + \varphi_{(2)}^{j} f_{ik} \\ & + \alpha f_{ij}(1 - R_{sys}^{(1)}) + \beta f_{jk}(1 - R_{sys}^{(2)}) \end{aligned} \quad (5)$$

$$X_i = \begin{cases} 1 & \text{if new logistics center is located} \\ & \text{at the candidate point i} \\ 0 & \text{if not} \end{cases} \quad (6)$$

$$Y_j = \begin{cases} 1 & \text{if new distribution center is located} \\ & \text{at the candidate point j} \\ 0 & \text{if not} \end{cases} \quad (7)$$

ANALYSIS OF ALGORITHM

The 4-stage distribution network is constituted of factory, LC, DC and demand point. This network can be divided into two subparts: The first one is to decide the location of one LC and one DC and the second one is to select the reasonable distribution route in the defined network. And hybrid genetic algorithm is used in this study.

The chromosome is coded by binary system, which is: $[u_1, u_2, ..., u_m|v_1, v_2, ..., v_n]$. u_i = 1 refers to a LC which is established on candidate points, if no LC will be built; Also, v_j = 1 refers to DC which is established on candidate points. Under the condition that the logistics center and distribution center are decided, the former problem is transformed into 3-stage transportation problem: From factory to LC; from LC to DC; from DC to demand point. From the last problem, after the distribution program of the overall distribution network is calculated, the target value can be obtained and the reciprocal of the target value is served as adaptive number of chromosome:

- **Step 1:** Set parameters. Main parameters contain the maximum genetic generation "max-gen", pop-size, intersection probability P_c and mutation probability p_m
- **Step 2:** Initial conditions. Pop-size chromosomes are generated at random as initial group
- **Step 3:** Intersection calculation is operated by P_c
- **Step 4:** Mutation calculation is operated by P_m
- **Step 5:** Evaluation. After the expansive transportation problem of each chromosome is solved according to the known target value, adaptation number is calculated for each chromosome
- **Step 6:** Selection. Roulette method is used. At the same time, pop-size new chromosome is generated to assure the multifamily of the chromosome
- **Step 7:** Judging the maximum generation if Max-gen is reached; if not, go back to step 3; if so, calculation should end here and the result is obtained

NUMERICAL ANALYSIS

Assumed that there is only one manufactory of dairy industry in an area and two logistics centers will be built which are selected from four candidate points, also four distribution centers will be built selected from eight candidate points in order to meet the needs of twenty demand points. The parameters are shown as Table 1, 2, 3, 4 and 5.

Table 1: Fixed cost of logitics center i

Sequence No.	1	2	3	4
$V_{(1)}^i$ (wanyuan)	83	75	80	68
$\varphi_{(1)}^j$ (yuan.t^{-1})	1.1	0.9	1.2	1.0

Table 2: Unit cost from LC i to DC j (yuan.t^{-1})

No.	1	2	3	4
1	112	287	344	104
2	289	218	291	228
3	311	129	145	292
4	313	175	320	320
5	236	214	164	263
6	279	321	208	290
7	257	313	304	288
8	286	295	187	148

Table 3: Fixed cost and disposal cost of DC j

Sequence No.	1	2	3	4	5	6	7	8
$V_{(2)}^j$ (wanyuan)	30	41	23	35	28	32	40	36
$\varphi_{(2)}^j$ (yuan.t^{-1})	1.5	1.5	1.7	1.7	1.7	1.6	1.6	1.5

Table 4: Average demand of demand Point k (t.month^{-1})

1	2	3	4	5	6	7
253	229	223	187	253	181	193
8	9	10	11	12	13	14
247	224	203	228	251	235	240
15	16	17	18	19	20	
251	216	201	192	203	230	

Table 5: Unit cost from DC j to demand point k (yuan.t^{-1})

No.	1	2	3	4	5	6	7	8
1	33	41	63	20	20	60	55	35
2	50	5445	62	70	45	45	78	56
3	33	46	61	46	73	44	30	72
4	60	61	53	27	36	45	34	46
5	63	32	50	38	33	64	53	50
6	50	48	35	30	30	25	25	40
7	24	29	31	62	27	53	36	23
8	48	61	72	55	67	23	71	69
9	45	52	69	29	78	32	27	71
10	70	39	41	44	68	54	52	41
11	29	35	43	63	37	24	38	29
12	30	44	66	28	67	28	68	35
13	63	46	20	41	23	30	50	70
14	26	77	47	75	50	38	42	42
15	40	45	31	41	36	37	45	43
16	22	55	20	33	22	27	73	57
17	27	25	75	70	53	75	72	44
18	60	58	35	20	20	35	35	40
19	25	30	47	50	31	60	28	41
20	70	65	30	47	54	28	37	40

Table 6: The distribution program

D1	D2	D3	D4
C3 (226)	C2 (232)	C1 (256)	C6 (184)
C7 (196)	C10 (206)	C4 (190)	C8 (250)
C14 (243)	C13 (238)	C5 (256)	C11 (231)
C17 (204)	C15 (254)	C9 (227)	C12 (254)
C19 (206)	C16 (219)	C18 (195)	C20 (233)

Assumed that the demand obeys the normal school N (μ_k, σ_k^2) and the average number μ_k is shown as Table 4, $\sigma_k = 10$, $\alpha = 5\%$, $\beta = 3\%$. Following results can be obtained: $X_1 = X_4 = 1$, $Y_1 = Y_3 = Y_4 = Y_6 = 1$, $f_{23} = 1149$, $f_{24} = 1124$, $f_{41} = 1075$, $f_{46} = 1152$, $R_{sys}^{(1)} = 99.8\%$,

$R_{sys}^{(2)}$ = 99.1% and the total cost is: 3557430.375 yuan, so the distribution program is shown as Table 6.

From Table 6, D1 is selected as distribution center 1; C3 (226) is selected as the quantity 226 which is distributed from D1 to C3.

CONCLUSION

This study contributes the distribution in large area and puts forward that logistics center should be built near the factory and the distribution center should be built near the customer, also this paper considers the reliability as a measure of distribution service level besides cost. A mathematical model has been established, in which both the cost and the reliability are as the estimation of the distribution objective. Genetic algorithm is used to solve the model and the optimal solution is obtained, then the results show that the proposed model has signal function to dairy distribution network design.

ACKNOWLEDGMENT

This research was supported in part by MOE (Ministry of Education in China) Project of Humanities and Social Sciences (11YJC630287) and Youth Scholar Backbone Supporting Plan Project of Heilongjiang General Colleges and Universities (1253G028).

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