META HEURISTIC METHOD FOR A SUPPLY CHAIN NETWORK RECONFIGURATION

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Abstract. In this paper, we address a network optimization problem for supply chain network systems. Supply chain management (scm) has been drawing much attention for most companies. Among other factors, the reconfiguration of the existing supply chain network (scn) is essential to retain competitive edge. We suggest a meta heuristic algorithm to solve this problem. It has been implemented to evaluate several reconfiguration alternatives for warehouses distributed all nationwide, especially focusing on the warehouses in specific region of Japan, of a major household appliances company. We simulated two cases by using actual data to confirm the effectiveness of the proposed algorithm. Computational experiments show that the proposed heuristic is satisfactory in both speed and the quality of the solutions generated.

1 Introduction In the 1980s companies discovered new manufacturing technologies and strategies that allowed them to reduce costs and better compete in different markets. Strategies such as just-in-time manufacturing, kanban, lean manufacturing, total quality management, and others became very popular, and vast quantities of resources were invested in implementing these strategies. In the last few years, however, it has become clear that many companies have reduced manufacturing costs as much as is practically possible. Many of these companies are discovering that effective supply chain management (SCM) is the next step they need to take in order to increase profit and market share.

Nowadays, the importance of SCM has been recognized worldwide, and many companies have been applying this concept. From the production to the delivery of products to consumers, retailers, wholesalers, manufacturers and material suppliers are closely related and form a chain called a 'Supply Chain'. Initially the efficiency of the distribution system was dealt with only by an individual company. However, eventually, all the companies related to a specific product started adopting SCM to minimize the system-wide costs while satisfying service level requirements.

One of the most advanced cases in SCM is the "direct" model, which gives Dell computer direct access to their final customers, by making use of information technology and unifying the production, distribution, and sales information. Further, the cross-docking system employed by Wal-Mart, the continuous replenishment program (CRP) developed by P&G, efficient consumer response (ECR) in the grocery industry and quick response (QR) in fiber-related industries have been successfully implemented.

The earliest work in this area, although the term "supply chain" was not in vogue, was by Geoffrion and Graves [3]. They introduced a multi-commodity logistics network design model for optimizing annualized finished product flows from plants to the DC's to the final customers. Kim and Lee discussed the multi-stage production/distribution planning

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in relation to supply chain management concept [7] with capacitated facilities. A similar problem was also solved by Sim et.al. by using an heuristic method based on Lagrangian relaxation [15]

There are various SCM issues. One is the network configuration decision regarding the number, location, and capacity of warehouses and manufacturing plants. So far, mixed integer programming models have been widely used to configure facility locations, and improve overall operations (See, for instance, Shapiro[6]).

The reconfiguration of the existing supply chain network is essential to retain competitive edge. On the strategic level, however, even if we focus on a quantitative criterion such as cost, it is not unusual that various costs involved in supply chain network cannot easily be aggregated into the overall cost, because of their imprecision, indetermination and uncertainty. Furthermore, there are other qualitative criteria to evaluate the performance of supply chain network. In theses complex situations, as an overall evaluation, for instance, a simple weighted sum of criteria is not adequate. Instead, the outranking analysis which has been frequently used is the best suited. So far, various variants of the meta-heuristic algorithms, which are called Genetic Algorithm, Simulated Annealing, Tabu Search and others. These have, however, a weakness because of their arbitrariness and difficulty of coding. Among others, GAs is the most familiar and has been widely used (see Rogers and Bruen[12], Bruen and Maystre[11]) because of SCN is similar to multi step TSP category.

We present a Genetic Algorithm to decide an optimal number of warehouses with a new coding method. As an illustrative application, we conducted a Shapiro's data of the evaluation of various reconfiguration alternatives of the warehouses distributed all over the region.

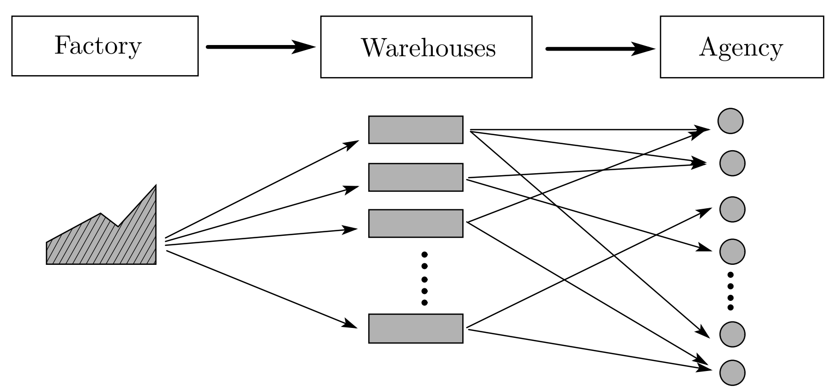

Figure 1: An example of distribution network

2 Meta Heuristic Method Approach Metaheuristics have proved to be very effective approaches to solving various NP-hard problems. Among such approaches, Genetic Algorithms, Tabu Search and Scatter Search have been used successfully in optimization problems. Genetic algorithms (GAs) were introduced by John Holland and researchers from the University of Michigan in 1976 [5]. In the last decade GAs have become widely used, however, GAs have not presented very good results for several optimization problems in their original model. However, GAs have been developed with improved operators.

GAs utilize three basic operation systems including selection, crossover, and mutation. Through these three evaluation processes, parents give birth to a new generation. The stronger individuals in every generation will have higher possibilities of survival and will pass part or all to the next generation (Goldberg 1989)[4]. Thus, the basic genetic algorithm may be summarized as follows([1],[2],[8],[9],[10]) :

Algorithm GA:

```
Begin
  Initialize population;
  Generation:=0;
  Repeat
      Generation=Generation+1
      Selection(population);
      Crossover(population);
      Mutation(population);
  Until Termination Criterion;
End
```

GAs provide a flow process with a rather simple system structure. However, it can produce a strong research capability for getting solutions, powerful especially as regards the issue of optimum combination (Goldberg, 1989,1994;Srinvas and Patnaik, 1994)[16]. In recent years, the application of GAs have been extended to financial problems, scheduling problems, and vehicle routing problems.

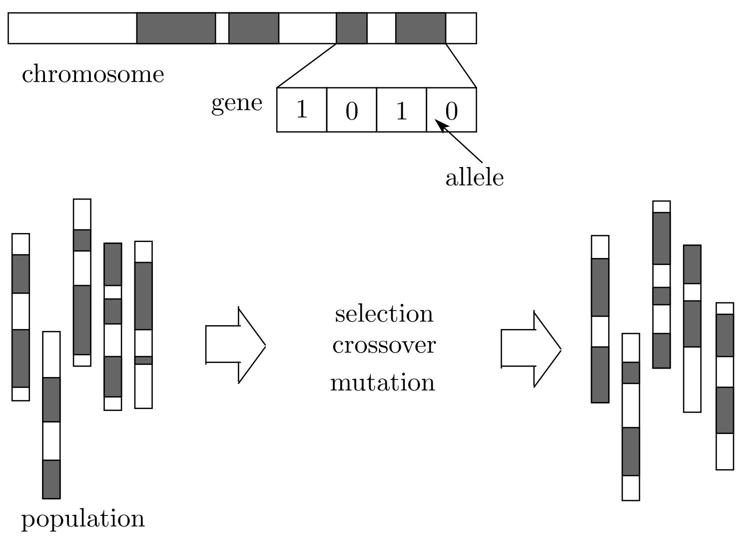

Figure 2: The basic concept of Genetic Algorithm

3 Problem Definition and Methodology This manuscript focuses on the development and validation of an efficient heuristic approach to address the following strongly interrelated problems.

1. The network configuration decision regarding the number, location, and capacity of warehouses and manufacturing plants. So far, mixed integer programming models have been widely used to configure facility locations, and improve overall operations.

2. Scheduling the available fleet of (company-owned or hired) transport vehicles to deliver all the produced quantities.

To pursue this objective, in this paper we treated a detailed mathematical model of the considered problem, explaining the available decision variables and the main constraints of the problem. An extensive model constitutes the first important contribution of this paper with respect to the related literature, which is mainly focused on simplified formulations taking into account only a part of the considered problem. Subsequently, the paper focuses on the development of an algorithm belonging to a class of modern problem-solving meta-heuristics that seem particularly suited to the considered problem, commonly referred to as Genetic Algorithms(GAs).

GAs are heuristic search techniques inspired from the principles of survival-of-the-fittest in natural evolution and genetics, which have been extensively used to solve combinatorial problems that cannot be handled by exhaustive or exact methods due to their prohibitive complexity. When properly configured, GAs are efficient and robust optimization tools, because they do not explicitly require additional information (such as convexity, or availability of derivative information) about the objective function to be optimized. For this reason, in the last decade, they have been applied to a considerable variety of problems, including scheduling and vehicle routing problems that are partially related to our cases.

We prepared two cases to use actual data. The first case is a one-stage delivery case of optimizing the SCN just between warehouse and agent. The next case is a two-stage delivery case where in we attempt to optimize all routes, factories-backline warehouses-frontline warehouses-agents.

4 Case Study-1: Optimization SCN of Company A Company A has many warehouses and agents all over Japan. There is a long demand chain of A's products consisting of construction dealers, agents, business offices, enterprises, and plants/ factories. The distribution process of company A is illustrated in Figure 1. As shown in Figure 1, the logistics network of A comprises a one-stage distribution system, where the warehouses are supplied from the factory. In order to secure one-day delivery service, warehouses are distributed in local regions. Since there are many restrictions (capacity of warehouses, variety of demand, etc.), it is a difficult and impractical process to store all items in the warehouses. Moreover, Company A has the problem of how many warehouses are needed.

4.1 Model Formulation We have the following variables: For each warehouse $i \in m$ and agency $j \in n$, d_{ij} is the cost from warehouse i to agency j . From each arc (i, j), the decision variable x_{ij} is equal to 1 if arc (i, j) is used (delivered) and 0 in other cases, and variable y_i indicates where warehouse j will hold goods or not it. Furthermore, f_j indicates the fixed for the warehouse, w_i is demand of agency and C_j is the capacity of the warehouse. We minimize the total cost that consists of travel or time cost plus and a fixed cost. The object is, firstly, to minimize total cost and then to decide the decision variable y_j.

$$\begin{aligned}
\text{Minimize} \quad & \sum_{i}^{m}\sum_{j}^{n} d_{ij}x_{ij} + \sum_{j}^{n} f_j y_j \\
\text{subject to} \quad & \sum x_{ij} = 1 \\
& \sum w_i x_{ij} \le C_j y_j
\end{aligned}$$

where,

$$x_{ij} = \begin{cases} 1: & \text{delivered from warehouse } j \text{ to agent } i \\ 0: & \text{not delivered warehouse } j \text{ to agent } i, \end{cases}$$

$$y_j = \begin{cases} 1: & \text{hold warehouse } j \\ 0: & \text{not hold warehouse } j. \end{cases}$$

4.2 Numerical Study We examined the effectiveness of merging some warehouses distributed all over the nation. Some of the advantages of merging are as follows:
(a) reduction of the safety inventory.
(b) reduction of the operating cost.

Using genetic algorithms for SCN is similar to the TSP or Job Shop Scheduling Problem, as it often involves the use of order or position dependent genomes, since the optimum or best sequence of activities is sought. Hence, an illegal solution may have the same value multiple times in the genome (“ superposition ”) and be missing other values. A technique that prevents creation of these ‘ lethal ’ individuals is important for the efficient execution of a GA, and is presented in Han & Tabata (2003)[13].

Cost
It is difficult to aggregate distribution, handling and storage cost into an overall cost, because it is difficult to estimate precisely the cost values due to time and cost constraints. Therefore, we have decided to look at all these costs separately.

Total inventory
Estimate the warehouses stock/inventory.
Since a low inventory stock is preferred, the better, this is a minimization criterion.

Restrictions
Consider capacities of warehouses and agencies
Each agency can receive the products from just one warehouse

Our numerical experiments were run on a MacBook Intel Core Duo-2GHz Processor, MacOsX Operating System using the Program Language C. We tested two methods ; Genetic Algorithm, and Branch and Bound, so as to evaluate the performance treating a data from Shapiro. We found that the speed of convergence is very sensitive to the setting of GA-parameters. However, the computational study on a set of benchmark problems indicated that our GA-based heuristic is capable of generating optimal solutions for small-size problems as well as high-quality solutions for large-size problems. The algorithm outperforms any of the previous heuristics in terms of solution quality. The computational times of the algorithm are very reasonable for all problem instances from the heuristic viewpoint. In addition, the numerical experiment used a delivery plan problem, which is shown in Table 1.

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We tested two methods; Genetic Algorithm, and Branch and Bound, so as to evaluate the performance treating a data of Shapiro.

The best result from branch and bound method is Table 3. This table indicates that the warehouse A, C, E, G should be kept in the all warehouses.

	fixed cost		a	b	c	d	e	f	g	h
A	134	A	148.5828	169.287	113.022	130.4688	256.128	112.29	63.6528	25.05
B	140	B	156.6288	154.9092	72.8364	53.7972	103.2516	13.002	29.904	207.414
C	160	C	197.3952	176.7078	79.2948	38.124	22.4112	73.284	22.8552	324.648
D	225	D	389.4264	349.2414	213.486	196.1268	275.3376	261.222	62.7984	576.15
E	142	E	284.292	273.1782	165.7656	152.496	212.9064	156.615	39.3024	317.634
F	285	F	54.1764	11.595	49.8732	114.7956	308.154	180.255	93.984	347.694
G	140	G	292.8744	256.4814	139.932	108.8652	123.2616	169.026	34.176	470.94
H	280	H	344.9052	339.9654	238.602	258.8196	443.4216	286.635	103.1688	374.748
		demand	894	773	598	706	1334	985	356	1670

i	j	k	l	m	n	o	p	q	r
28.812	56.1516	28.5768	42.4848	52.632	102.8016	203.3838	263.4	332.2752	397.9764
85.848	129.2256	50.5764	42.6852	94.248	139.0512	171.7902	279.204	255.9252	249.246
120.54	172.6854	72.576	55.5108	119.952	163.4064	186.9288	298.1688	220.4988	164.2572
189.924	295.7574	107.5032	73.7472	151.776	169.3536	178.3722	218.0952	14.0484	189.5904
110.25	135.3792	44.4528	18.2364	82.2528	96.5712	12.5058	146.4504	164.3052	266.4072
114.954	183.0696	105.0084	101.0016	137.088	202.7712	375.174	434.0832	437.3328	446.1912
162.582	220.3758	95.256	67.5348	144.9216	179.832	188.2452	285.5256	133.7652	26.1504
104.958	105.3804	60.5556	58.5168	45.7776	7.9296	219.1806	128.5392	342.6588	529.5456
490	641	378	334	408	472	1097	878	1018	1362

s	t	Capacity
101.088	101.9472	7500
64.3968	87.3144	6000
54.4752	80.7216	6500
74.5056	23.6376	8000
86.8608	53.7072	6800
90.2304	136.68	7200
34.8192	59.8176	5500
145.08	89.7264	4500
312	268	

Table 1: Cost of delivery from warehouse to agency and Capacity of each warehouse

Crossover Probability	0.6
Mutation Probability	0.2
Selection Method	Roulette wheel Strategy
Population Size	20
Generations	5000
Random number	Mersenne Twister Algorithm

Table 2: Setting of GA-parameters

Y_j	X_{ij}	a	b	c	d	e	f	g	h	i	j	k	l	m
1	A	1	1	0	0	0	0	0	1	1	1	1	0	1
0	B	0	0	0	0	0	0	0	0	0	0	0	0	0
1	C	0	0	1	1	1	1	1	0	0	0	0	0	0
0	D	0	0	0	0	0	0	0	0	0	0	0	0	0
1	E	0	0	0	0	0	0	0	0	0	0	0	1	0
0	F	0	0	0	0	0	0	0	0	0	0	0	0	0
1	G	0	0	0	0	0	0	0	0	0	0	0	0	0
0	H	0	0	0	0	0	0	0	0	0	0	0	0	0
		1	1	1	1	1	1	1	1	1	1	1	1	1
		1	1	1	1	1	1	1	1	1	1	1	1	1
	Demand	894	773	598	706	1334	985	356	1670	490	641	378	334	408

n	o	p	q	r	s	t
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
1	1	1	0	0	0	1
0	0	0	0	0	0	0
0	0	0	1	1	1	0
0	0	0	0	0	0	0
1	1	1	1	1	1	1
1	1	1	1	1	1	1
472	1097	878	1018	1362	312	268

	TOTAL COST
Objective function	1843.2672

				Capacity
Restrict	5254	<?	7500	7500
	0	<?	6000	0
	3979	<?	6500	6500
	0	<?	8000	0
	3049	<?	6800	6800
	0	<?	7200	0
	2692	<?	5500	5500
	0	<?	4500	0

Table 3: Result of Branch and Bound Method

The result from GA is below in Table 4. This solution has a matrix-form because of chromosome is coded as matrix-form. By this coding method, we can control lethal genes conveniently.

1 1 0 0 0 0 0 1 1 1 1 0 1 0 0 0 0 0 0 0	**1**
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	**0**
0 0 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0	**1**
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	**0**
0 0 0 0 0 0 0 0 0 0 0 1 0 1 1 1 0 0 0 1	**1**
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	**0**
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 0	**1**
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	**0**

Table 4: Result of GA

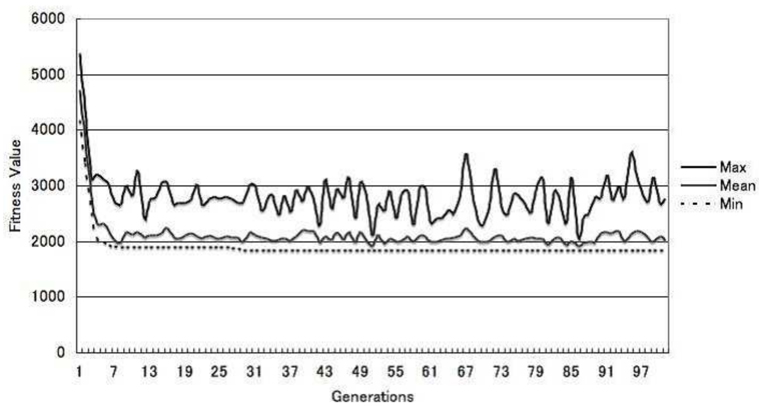

Figure 3: Fitness value of GA process

GAs contain operators called crossover and mutation, the ones that specially affect performance of GA. Therefore, it is very important to specify the GA's parameter for getting a good performance. However it is very troublesome to identify GA-parameters. In the present paper, we use Experimental Design Method to setup GA parameters proposed by HAN [13] and then set up as Table 2. Validation of an analytical method through a series of experiments demonstrates that the method is suitable for its intended purpose. By Experimental Design method , we can expect to get a better result and to reduce the cost.

The results are shown in Table 4. and Figure 3. Computational experiments shows the proposed heuristic is satisfactory in both speed and the quality of the solutions generated.

5 Case Study-2 : Expansion version of Company A Logistics network of A comprises of two-stage distribution system, where frontline warehouses order from backline warehouses, the backline warehouses are supplied from factory. In order to secure one-day delivery service, frontline warehouses are distributed in local regions.Since, more than 10,000 items are handled, it is a difficult and impractical process to store all items in the frontline warehouses. Therefore only high demand items are stocked and other items are delivered from backline warehouses in two days.

We are examining the possibilities of merging the frontline warehouses distributed all over the nation.

Some of the advantages of merging are as follows:
(a) reduction in the safety inventory
(b) reduction in the operating cost
(c) increase in the handling items

Some of the disadvantages are:
(a) increase in the cost of delivery due to the distance of some frontline warehouse to the customers
(b) reduction in the level of delivery service

Company A has many warehouses and agents all over Japan. There is a long demand chains of A's products consisting of construction dealers, agents, business offices, enterprises, and plants/ factories. The distribution process of company A is shown in Figure 4. below:

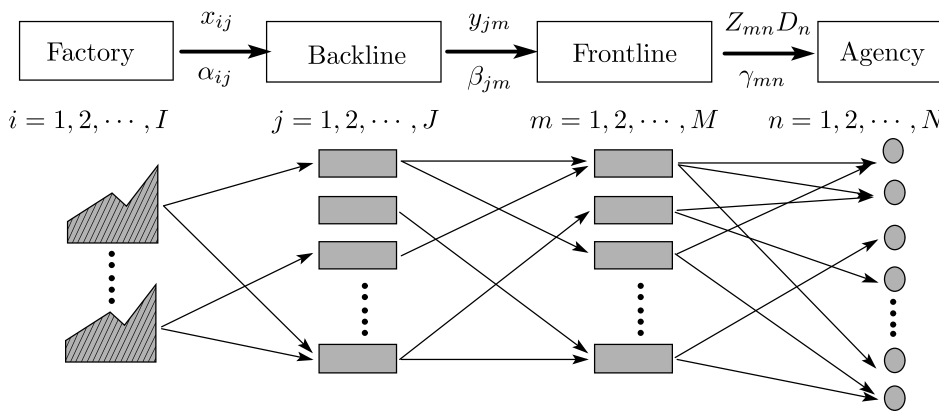

Figure 4: A expanded model of Case Study-1

5.1 Model Formulation This problem is formulated as below, and it has the following variables:

For each backline-warehouse $i \in j$, frontline-warehouse $j \in m$ and agency $m \in n$, α_{ij} is the cost (per unit) from factory i to backline-warehouse j. $x_{i,j}$ indicates the quantity of items from factory i to backline-warehouse j, the decision variable U_j is equal to 1 if arc (i, j) is used (delivered) and 0 others, and variable V_m indicates that agent j will be held or not it. Furthermore, Z_{mn} indicates that agent n is selected or not. We minimize the total cost that consist of travel or time cost and a fixed cost. The object is, minimizing total operation cost at the same time optimization of all routes.

To facilitate the problem formulation, consider the following notations:
α_{ij}: transaction cost from factory i to backline warehouse j (yen/unit)
x_{ij}: transaction quantity from backline-warehouse j to frontline-warehouse j(unit)
β_{jm}: transaction cost from backline-warehouse j to backline-warehouse m (yen/unit)
y_{jm}: transaction quantity from backline-warehouse j to frontline-warehouse m(unit)
R_m: holding cost of frontline-warehouse m
K_i: capacity of factory i
C_j: capacity of backline-warehouses j

E_m: capacity of frontline-warehouses m
D_n: quantity demanded of agent n
γ_{mn}: transaction cost from frontline-warehouses m to agent n (yen/unit)
U_j: the 0-1 variable concerning the use of path $i \to j$
V_m: the 0-1 variable concerning the use of path $j \to m$
Z_{mn}: the 0-1 variable concerning the use of path $m \to n$

With these notations, we consider the model below that is an expanded version of case company A. The objective function has four cost terms: the operation costs from factories to backline-warehouses, the operation costs from backline-warehouses to frontline-warehouses, the operation costs from frontline-warehouses to agents and fixed costs of using arcs to transport demand.

$$
\begin{aligned}
\text{Minimize} \quad & \left(\sum_{i=1}^{I} \sum_{j=1}^{J} \alpha_{ij} x_{ij} + \sum_{j=1}^{J} \sum_{m=1}^{M} \beta_{jm} y_{jm} + \sum_{m=1}^{M} \sum_{n=1}^{N} D_n Z_{mn} \gamma_{mn} + \sum_{m=1}^{M} R_m V_m \right) \\
\text{subject to} \quad & \sum_{j=1}^{J} x_{ij} \leq K_i, i = 1, 2, \cdots, I \\
& \sum_{i=1}^{I} x_{ij} \leq C_j U_j, j = 1, 2, \cdots, J \\
& \sum_{m=1}^{M} y_{jm} \leq \sum_{i=1}^{I} x_{ij}, j = 1, 2, \cdots, J \\
& \sum_{j=1}^{J} y_{jm} \geq \sum_{n=1}^{N} D_n Z_{mn}, m = 1, 2, \cdots, M \\
& \sum_{n=1}^{N} D_n Z_{mn} \leq E_m V_m, \ m = 1, 2, \cdots, M \\
& \sum_{m=1}^{M} z_{mn} = 1, n = 1, 2, \cdots, N \\
& V_m = \{0, 1\}, m = 1, 2, \cdots, M \\
& z_{mn} = \{0, 1\}, m = 1, 2, \cdots, M; n = 1, 2, \cdots, N \\
& x_{ij} \geq 0, i = 1, 2, \cdots, I; j = 1, 2, \cdots, J \\
& y_{jm} \geq 0, j = 1, 2, \cdots, J; m = 1, 2, \cdots, M
\end{aligned}
$$

5.2 Numerical Study It is very difficult to consider total cost in this case, because of that composed two-stage delivery system.

Cost

It is difficult to aggregate distribution, handling and storage cost, into an overall cost, because it is difficult to estimate precisely the cost values due to time and cost constraints. Therefore, we have decided to look at all these costs separately.

Total inventory

Estimate the warehouses stock/inventory.

Since lesser the inventory stock, the better, this is a minimization criterion.

Restrictions

Consider capacities of warehouses and agencies

In this case, we considered two backline-warehouses and two factories as table 5 and 6.

	A	B	C	D	E	F	G	H	capacity
back-1	50	66	57	55	58	34	54	5	8900
back-2	18	53	60	37	23	23	4	25	7200

Table 5: delivery cost from backline-warehouses to frontline-warehouses

	back-1	back-2	capacity
factory-1	34	66	12000
factory-2	53	70	5200

Table 6: delivery cost from factories to backline-warehouses

	fixed cost		a	b	c	d	e	f	g	h
A	13400	A	14858	16929	11302	13047	25613	11229	6365	2505
B	1400	B	15663	15491	7284	5380	10325	1300	2990	20741
C	16000	C	17671	17671	7929	3812	2241	7328	2286	32465
D	22500	D	34924	34924	21349	19613	27534	26122	6280	57615
E	14200	E	27318	27318	16577	15250	21291	15662	3930	31763
F	28500	F	1160	1160	4987	11480	30815	18026	9398	34769
G	14000	G	25648	25648	13993	10887	12326	16903	3418	47094
H	28000	H	33997	33997	23860	25882	44342	28664	10317	37475
		demand	894	773	598	706	1334	985	356	1670

i	j	k	l	m	n	o	p	q	r
2881	5615	2858	4248	5263	10280	20338	26340	33228	39798
8585	12923	5058	4269	9425	13905	17179	27920	25593	24925
12054	17269	7258	5551	11995	16341	18693	29817	22050	16426
18992	29576	10750	7375	15178	16935	17837	21810	1405	18959
11025	13538	4445	1824	8225	9657	1251	14645	16431	26641
11495	18307	10501	10100	13709	20277	37517	43408	43733	44619
16258	22038	9526	6753	14492	17983	18825	28553	13377	2615
10496	10538	6056	5852	4578	793	21918	12854	34266	52955
490	641	378	334	408	472	1097	878	1018	1362

s	t	Capacity
10109	10195	7500
6440	8731	6000
5448	8072	6500
7451	2364	8000
8686	5371	6800
9023	13668	7200
3482	5982	5500
14508	8973	4500
312	268	

Table 7: Cost of delivery from front-warehouse to agencies and Capacity of each warehouses

Results of simulations

· total cost from factory to backline-warehouse: 1181604

· total cost from backline-warehouse to frontline-warehouse: 430192

· total cost from frontline-warehouse to agent: 236544

· total cost of SCN: **1848340**

We tested two methods, Genetic Algorithm and Branch & Bound method, so as to evaluate the performance treating a data of Shapiro in case-1. In this case-2, we tested real-SCN problem with real data. From this simulations, we know that GA is very effective to do the decision making as in this case. The best result is described in table 8, and total result is below it. Tables 8 indicates that the warehouse A, F, G, H are should be kept in the all warehouses and cost of between factory and backline-warehouse & backline-warehouse and frontline-warehouse.

	back-1	back-2
fac-1	7774	4226
fac-2	0	2974

	A	B	C	D	E	F	G	H
back-1	48	0	0	0	0	3250	0	4476
back-2	2112	0	0	0	0	0	5088	0

	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	
A	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	**1**
B	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
C	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
D	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
E	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
F	1	1	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	**1**
G	0	0	0	1	1	0	1	0	0	0	0	0	0	0	0	0	1	1	1	0	**1**
H	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	0	0	0	1	**1**

Table 8: The best result of simulations

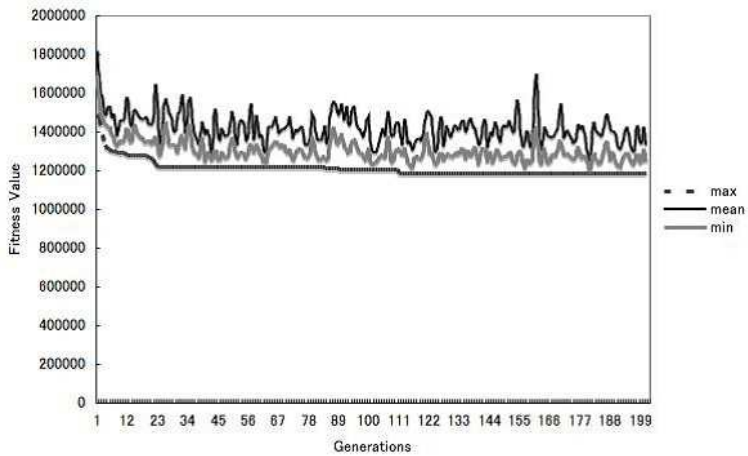

Figure 5: Fitness value of GA process

6 Concluding Remarks Even if the result of alternatives do not seem to provide enough insight on decision making, by carrying out a genetic algorithm method, we can derive the overall solution by making the best use of them. In general, the relative importance of criteria is ambiguous and the scores are imprecise. This suggests that, in such cases, a genetic algorithm method is useful. Moreover, we modified the coding method of chromosomes to adapt them appropriately to SCN with controlling lethal gene.

Furthermore, we compared GA and Branch and Bound method to identify the validity of GA. Our proposed algorithm takes much more computational time than others, but it is a trifling difference, because our focus is not the speed of algorithm but the accuracy of the result. GA is valid not only for the realistic problem but also for the homogeneous combinatorial optimization problem.

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