Using the Analytic Hierarchy Process Method in reconfiguration of Supply Chain Network
- Case of company H.T. -

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Abstract

Nowadays, within new important strategies for the cost reduction and the problem of environmental protection, logistics plays a key role in the corporate competition. Because of this reason, firm must consider so many situations, including a multi criteria problem which includes both minimum cost and customer's satisfaction factors, for example delivering cost, the number of warehouses, safety and etc... . Especially, it is very important to reconfigure Supply Chain Network. In this work, we suggested to integrate Analytic Hierarchy Process (AHP) to determine the best alternative which is merged or not. Finally, detailed example is presented as a case of Japanese company H.T..

Keywords: Supply Chain Network, Analytic Hierarchy Process, Pseudo-criterion and Outranking

1. Introduction

There are various decision-making methods, among which AHP (analytical hierarchy process) technique has been developed as a useful and simple method to deal with decision-making problems. Just as it was said, “AHP (Saaty, Golden et al.) has been applied in a variety of areas as a useful and practical multi-criteria decision analysis tool.” In the area of SCM (Supply Chain Management), we prefer to use AHP method. Here goes the definition of supply chain and supply chain management given by American Supply Chain Association. The supply chain - a term now commonly used internationally - encompasses every effort involved in producing and delivering a final product or service, from the supplier's suppliers to the customer's customers.

SCM has been drawing much attention for most companies. Among others, the reconfiguration of the existing supply chain network is essential to retain their competitive edges. In the strategic level, however, even if we focus on the quantitative criterion such as cost, however, there are situations that it is not easy to aggregate various costs into the overall cost, because of their imprecision, indetermination and uncertainty.

In this paper, we focus to SCN (Supply Chain Network) optimization in SCM. The core of SCN is a network optimization problem. The number of warehouses is very important in the supply chain, because of warehouse management is not only reduce the logistic cost but also influence to performance in the SCN. Thus we develop an AHP simulation methodology to deal with SCN problems. 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).

Logistics is a very important area for achieving corporate competition. In most industries the cost of distribution, such that in some cases it can account for up to 66% (See, Figure1.) in total logistic cost. In this paper, firstly, we use AHP for uncertain weight which are linguistic expressions; then, determined each of warehouses' weight by using identified factors; finally, comparing the result of AHP.

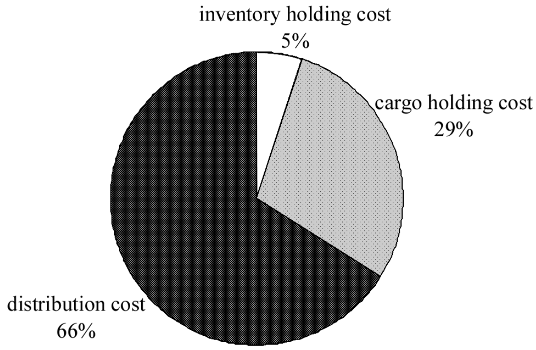

Figure 1. the ration of Logistic relation costs

(2009 Japan Institute Logistic System)

This paper is organized as follows. In Section 2, introduced AHP. In section 3, propose the problem description utilizing case. In section 4, we discuss a simplified specific SCN problem utilizing case, examining the uncertainty by using simulation approach of AHP. Some concluding remarks are finally given in Section 5.

2. AHP

In this section, we shall briefly review a AHP method. In most situations the decision maker's pair-wise comparisons would contain a degree of uncertainty. We adhere to the original axioms of AHP with one exception: we assume a continuous ratio scale from 1 to 9 for preference matrices so that we can observe the probability of rank reversal over a wide range of uncertainties (between 2% and 20%). We assume that all uncertainties in the preference matrix result from doubts expressed by an individual decision maker as to the accuracy of his or her judgments. According to Zahedi, there are two sources of this judgmental uncertainty in this specific decision-making problem in SCM.

With a pool of potential options, AHP make pair comparison and helps to determine which alternative is the better than the other criteria. If there is not any constraint for problem, AHP is enough for making decision, such as single source which is mentioned in this article. If the value for alternative and are respectively and, the preference of alternative is to is equal to/ . Hence the pair-wise comparison matrix is;

$$W_1 / W_1 \; W_1 / W_2 \ldots\ldots W_1 / W_n,$$
$$W_2 / W_1 \; W_2 / W_2 \ldots\ldots W_2 / W_n,$$
$$W_n / W_1 \; W_n / W_2 \ldots\ldots W_n / W_n,$$

As this matrix is consistent the weight of each element is its relative normalized amount

Weight of $\boldsymbol{i}$ th element = $\dfrac{w_i}{\sum_{i=1}^{n} w_i}$.

The priority of alternative $\boldsymbol{i}$ to $\boldsymbol{j}$ for negative criteria, such as cost, is equal to $\boldsymbol{w_j} / \boldsymbol{w_i}$, then the pair-wise comparison matrix is;

As this matrix is also consistent, the weights of elements are the normalized amount of any columns, which is equal to the inverse normalized amount of the alternatives:

Weight of th element (for negative criteria) = $\dfrac{\frac{1}{w_i}}{\sum_{i=1}^{n} \frac{1}{w_i}}$.

3. Problem description

- A Case Study: Reconfiguration Problem of Company HT -

Company HT has many warehouses and agents all over Japan. There is a long demand chains of HT's products consisting of construction dealers, agents, business offices, enterprises, and plants/factories. The distribution process of company HT is illustrated in Figure 1. As shown in Figure 1, logistics network of HT 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.

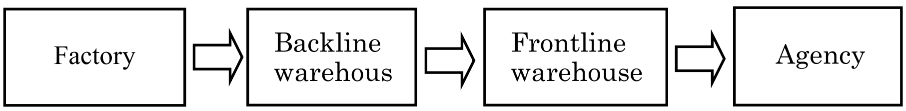

Figure 2. Company HT's distribution process

Problem Formulation

We are examining the effectiveness of merging some frontline warehouses distributed all over the nation. Some of the advantages of merging are as follows:

(a) to reduce the safety inventory.

(b) to reduce the operating cost.

Some of the disadvantages are:

(a) to increase in the cost of delivery due to the distance of some frontline warehouse to the customers.

(b) to decrease the level of delivery service.

Taking into account the advantages, disadvantages and the existence of competitors, we consider the following strategies:

・Strategy 1: The frontline warehouse in the North East region is merged into 'Kanto' warehouse.

・Strategy 2: The status quo (non-merging).

・Strategy 3: The frontline warehouse in the North East region is used as a depot.

Three strategies have different inventory and distribution systems. Therefore, they can be subdivided into 4 alternatives.

Alternative 1 merging and non-operating (see Figure 3):

- The frontline warehouse in the North-East region (this region is surrounded by the circle in the figure) is merged into 'Kanto' warehouse (its location is depicted by star in the figure).

Figure 3. Alternative 1

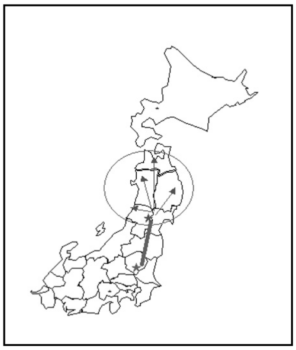

Figure 4. Alternative 2

- Customers in North-East region will receive the products in one day (the following day) from the 'Kanto' warehouse.

Alternative 2 the status quo (see Figure 4):

- the frontline warehouse in the North-East region (it is depicted by star within the circle) is not merged and only 50% of all items will be stocked/stored for one day delivery.
- the rest will be delivered from 'Kanto' warehouse in 2 days

Alternative 3 operating as a depot and one day delivery (see Figure 5)

- the frontline warehouse in the North-East region is merged into the 'Kanto' warehouse and operating as a depot (no storage).
- the one day delivery from the 'Kanto' warehouse via the depot to all over North East region except for customers in some part of the North-East region that are directly one day delivered from 'Kanto' warehouse.

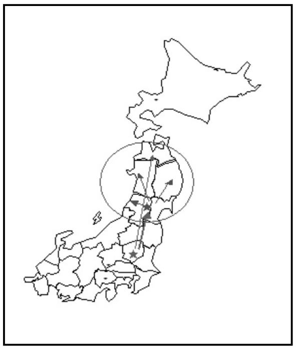

Figure 5. Alternative 3

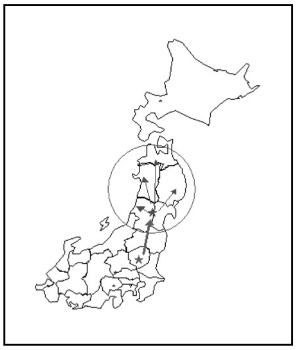

Figure 6. Alternative 4

Alternative 4 operating as a depot and two day delivery in some part (see Figure 6)

- Warehouse in North-East region is merged into the 'Kanto' warehouse and operating as a depot.
- All customers in North-East region will receive products via the depot from 'Kanto' warehouse. Therefore, some customers receive 2 day delivery service.

Criteria for Consideration:

The following are the criteria for considerations.

- Cost
  - Distribution cost
  - Handling cost
  - Storage cost
- Total inventory
- Customer satisfaction
  - Number of items delivered in one day (the following day)
  - Number of regions delivered in one day (the following day)
- Competitive advantage

Cost

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

ranking with AHP	
Significant reduction compared to the status quo	9
Some reduction compared to the status quo	7
Same as the status quo	5
Higher than the status quo	3
Significantly high compared to the status quo	1

Total inventory

Estimate the backline + frontline warehouses stock/inventory. Since lesser the inventory stock, the better, this is a minimization Criterion. In order to convert this into a maximization criterion, define the following:

Inventory score = large value – estimated value.

Customer satisfaction

We look at the number of items delivered in a day and use it as the score. If all regions are delivered in one day, then score is 2 and if some regions are delivered in 2 days, we take 1 as a score

Competitive advantage

a	If the North East region is the stock/storing base	3 point
b	If the North East region is operating as a depot	2 point
c	If the North East region is not operating	1 point

4. Approach of AHP

Consider a scenario where a core enterprise in a supply chain is faced with a decision-making problem, i.e. choosing one best supplier from the four suppliers. Aiming for this supplier selection problem in SCM, we prefer to use AHP simulation approach, because it not only overcomes the limitations of AHP but also seems technically feasible. Firstly; we must determine which criteria affect to our problem. We determine main and sub criteria in Figure 7.

4-1. Establish the hierarchy

To show the method proposed in the previous section, we discuss a simplified problem. Here is the scenario: HT Company is the core enterprise in the supply chain. It encounters the problem of reconfiguration SCN problem. The important selection criteria for this case include quality, price, delivery, service, management and culture, technology, financial situation etc. There are four alternatives: Alternative 1, Alternative 2, Alternative 3, and Alternative 4.

As we know, "In the AHP, a decision process is modeled as a hierarchy. At each level in the hierarchy, the decision maker is required to make pair-wise comparisons between decision alternatives and criteria using a ratio scale. The AHP then determines the relative ranks of the decision alternatives. The weights of the decision alternatives are given by the elements of the normalized principal right-hand eigenvector of a preference matrix consisting of the pair-wise comparisons between alternatives." [6] The traditional methodology of AHP includes four steps: firstly, establish the structure of the hierarchy; secondly, construct the pair-wise judgmental matrices; thirdly, sole rank and consistency inspection.

Thus, we construct the general hierarchy investigated in this research. All preference matrices were 4 by 4 and there were four matrices at each level, shown by Figure 7.

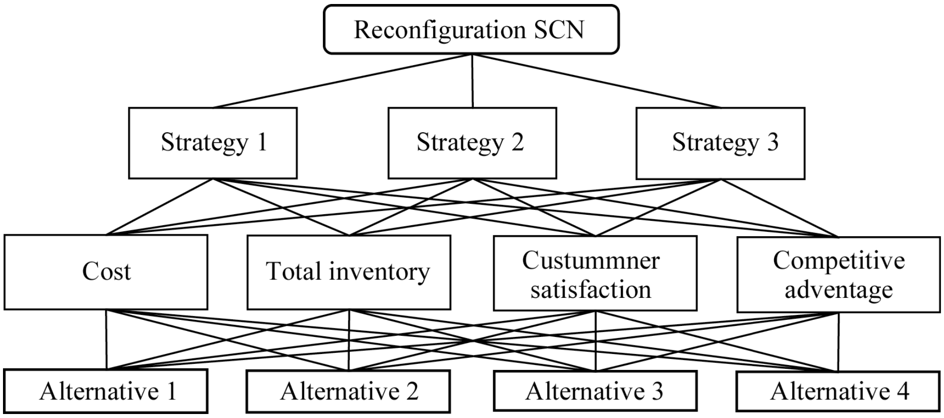

Figure 7. the AHP hierarchy of problem

4-2. Construct pair-wise comparison matrix

Comparison main-matrices are 3 by 3 and there are four matrices at each level as depicted in Figure 7. and Figure 8 shows the ratio scale used in this research. The ratio scale used in constructing the judgmental matrix of the preference matrices.

1	equally important	1	equally important
3	a little important	1/3	a little unimportant
5	important	1/5	unimportant
7	equally important	1/7	very unimportant
9	extremely important	1/9	extremely unimportant

Figure 8. Ratio scale used in constructing the judgmental matrix

Hence the weight vector of alternatives W_i={0.31,0.22,0.21,0.13} as table1. . Now we must normalised each of criteria as Table 2. , because we want to show total of that criteria =1. So if Normalised them; All of alternative weight is respectively W_i={0.36, 0.25 , 0.25 , 0.15} found.

Table 1. Overal rating of criteria

Criterion	Weight	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Cost	0.36	0.52	0.20	0.13	0.16
Total inventory	0.14	0.20	0.38	0.27	0.15
Customer Satisfaction	0.30	0.25	0.28	0.36	0.11
Competitive	0.2	0.23	0.30	0.29	0.18
Average Weight		0.31	0.22	0.21	0.13

Table 1. shows that ʻAlternative-1ʼ gets a very good rating for ʻcostʼ but is poor in criterion of ʻtotal inventoryʼ. On the other hand ʻAlternative-3ʼ is in term of ʻcustomer satisfactionʼ. This means that the final decision will be particularly sensitive to the precise weights assigned to these two heavily weighted

criteria. Had the two competing methods performed equally well in respect of these criteria, then the weights assigned to these criteria would not be critical to the final decision.

5. Conclusions

In this article, we discussed an integrated model for reconfiguration of supply chain network with using AHP techniques. Our aimed determined the best alternative with optimal appointment of quantities. We suggested an example, which involve an example product and on that example, we develop a AHP model for reconfiguration of SCN problems. By Using AHP, we transformed each linguistic weight to crisp value and made up a mathematical model. The Result is shown in Figure 7. We believe that this model a new approach to determining good solution of SCN. Factors are directing administrator to decrease their cost and search different and suitable supplier from different location. And, the AHP makes the selection process very transparent. This is of great benefit in a SCM environment since it reveals in detail administrator's policy. This in turn reveals the extent to which decision maker understand the objectives of problem. It also reveals his understanding of the alternative solutions since these must be understood if their relative merits are to be assessed correctly.

6. References

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