Comparing GA-AHP and Outranking Analysis
—The case of reconfigures the Supply Chain Network—

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Supply Chain Management (SCM) has attracted a lot of attention for most companies. Among them, to maintain their competitiveness is essential to reconfigure supply chain network (SCN) of existing. 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. Furthermore, other qualitative criteria must be taken in to account for evaluating the performance of supply chain network. In these complex situation, heuristic approach which has been frequently used is the best suited. However, general approach does not often include an opinion and intuition of the decision-maker. This paper focused to Outranking Analysis as ELECTRE-III and Analytic Hierarchy Process (AHP) with Genetic Algorithm (GA). They have been implemented in the evaluation of several reconfiguration alternatives of the warehouses distributed on the wide region. This paper presents an interactive multi-criteria outranking analysis. It has been implemented in the evaluation of several reconfiguration alternatives of the warehouses distributed all over the nation, especially focusing on the possibility of merging the warehouse in North East region in Japan, of a major household appliances company. We expect that our two approaches have played a proper human-machine role in the real world decision-making.

Keywords: Analytic Hierarchy Process, supply chain network, outranking analysis, genetic algorithm, multi-criteria analysis, ELECTRE-III

1. Introduction

Firms market be globalization, sourcing, manufacturing, regional specialization and the world needed a product strategy 'era of limitless competition in accordance with high quality, low price, timely delivery and the growing importance of 60% to 70% of the supply chain value is generated in a portion other than the manufacture, so that the entire line has been needed is manageable. Initially only an individual company has dealt the efficiency of distribution system. 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, cross-docking system employed by Wal-Mart, continuous replenishment program (CRP) developed by P&G, efficient consumer response (ECR) in the grocery industry and quick response (QR) in fiber-related industries has been successfully implemented.

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).

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, 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 these 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 outranking analysis, which are called ELECTRE I, II, III, IV, IS and others. Among others, ELECTRE III is the most familiar and has been widely used (see Rogers and Bruen and Rogers, Bruen and Maystre). It is flexible in that it allows us to set many parameters like threshold values. It has, however, a weakness because of their arbitrariness at the same time. A

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way to overcome this difficulty is to perform the sensitivity analysis.

In this paper, we present an interactive multiple criteria outranking analysis and GA-AHP to evaluate and rank alternatives. As an illustrative application, we conducted a case study of the evaluation of various reconfiguration alternatives of the warehouses distributed all over the nation, especially focusing on the possibility of merging the warehouse in North East region in Japan, of a major household appliances company, say, company, hereafter.

2. Analytic Hierarchy Process (AHP) with Genetic Algorithm (GA)

Since its invention, AHP has been a tool available to decision-makers and researchers and is one of the most widely used multiple criteria decision-making tools (Vaidya and Kumar 2006) [4]. It is designed to cope with both the rational and the intuitive of decision-maker's to select the best from a number of alternatives evaluated with respect to several criteria. In this process, the decision maker carries out simple pairwise comparison judgments, which are then used to develop overall priorities for ranking the alternatives (Saaty and Vargas 2001) [13].

The form of matrix of the pair-wise comparisons is as follows:

$$A = \begin{array}{c} \\ A_1 \\ A_2 \\ \vdots \\ A_n \end{array} \begin{array}{c} \begin{array}{cccc} A_1 & A_2 & \cdots & A_n \end{array} \\ \begin{pmatrix} w_1/w_1 & w_1/w_2 & \cdots & w_1/w_n \\ w_2/w_1 & w_2/w_2 & \cdots & w_1/w_n \\ \vdots & \vdots & \ddots & \vdots \\ w_n/w_1 & w_n/w_2 & \cdots & w_n/w_n \end{pmatrix} \end{array}$$

The comparisons are made using a scale that indicates the importance of one element over another element with respect to a given attribute. Table 1 shows the scale ranges from 1 for 'the least valued than' to 9 for 'the most important than'.

Table 1. 1-9 Scale for the pair wise comparison (Saaty 2001)

Linguistic term	Preference number
Equally important	1
Weakly more important	3
Strongly more important	5
Very strong important	7
Absolutely more important	9
Intermediate values	2, 4, 6, 8

In the basic structure of an Analytic Hierarchy presented in Figure 1, the goal is specified at the top, all the objectives or criteria are listed below the goal and all alternatives are presented at the last level.

Some key and basic steps involved in this methodology are;

Step 1. Determine the problem.
Step 2. Structure the decision hierarchy of different levels constituting goal, criteria, sub-criteria and alternatives.
Step 3. Compare each element at the related level and establish priorities.
Step 4. Perform calculations to find the normalized values for each criteria / alternative. Calculate the maximum Eigen value and C.I..
Step 5. If the maximum Eigen value, C.I. is satisfactory, then the decision is made based on the normalized values. If not, the procedure adjusts the value of C.I. using GA.

In AHP approach, GA roles to decrease the value of consistency index (See [5]).

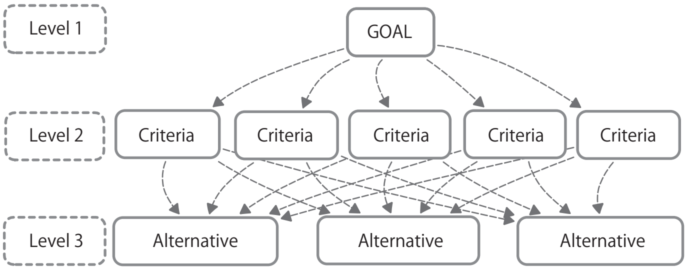

Figure 1. Basic structure of AHP

The consistency analysis is a part of the AHP method. It is to assure a certain quality level of the decision. The measure of inconsistency can be used to successively improve the consistency of judgments (Saaty and Vargas 2001) [13].

3. Pseudo-criterion and ELECTRE III

In this section, we shall briefly review a pseudo-criterion and outranking relation method with ELECTRE III. Let us consider n alternatives $\mathbf{a}_\mathrm{i}, i = 1, 2, ..., n.$ And let $\boldsymbol{A} = \{\mathbf{a}_\mathrm{i}\}.$

Let $g_1, g_2, ..., g_m$ be m-criteria. Thus, each alternative $\mathbf{a}_\mathrm{i}$ is characterized by a multi-attribute outcome denoted by a vector $\left(g_1(\mathbf{a}_\mathrm{i}), g_2(\mathbf{a}_\mathrm{i}), ..., g_m(\mathbf{a}_\mathrm{i})\right)$.

In what follows, we assume that the decision maker prefers larger to smaller values for each criterion. In the most traditional models, a true criterion precisely reflecting the preferences of the decision maker is assumed. In that case, the comparison between two alternatives $\mathbf{a}_\mathrm{i}$ and $\mathbf{a}_\mathrm{j}$ is made simply on the basis of the comparison between the numbers $g_k(\mathbf{a}_\mathrm{i})$ and $g_k(\mathbf{a}_\mathrm{j})$, that is, $\mathbf{a}_\mathrm{i}$ is preferred to $\mathbf{a}_\mathrm{j}$ if and only if $g_k(\mathbf{a}_\mathrm{i}) > g_k(\mathbf{a}_\mathrm{j})$ and $\mathbf{a}_\mathrm{i}$ is indifferent to $\mathbf{a}_\mathrm{j}$ if and only if $g_k(\mathbf{a}_\mathrm{i}) = g_k(\mathbf{a}_\mathrm{j})$,where $g_k(\mathbf{a})$ is the value of k-th criterion of an alternative $\mathbf{a}$. The underlying preference structure is called a complete preorder structure and $g_k(\mathbf{a})$ is called a true criterion (see Vincke[21]).

On the other hand, in the presence of imprecision, or uncertainty , it is often reasonable to admit that if a positive difference $g_k(\mathbf{a}_\mathrm{i}) - g_k(\mathbf{a}_\mathrm{j})$ is small, $\mathbf{a}_\mathrm{i}$ and $\mathbf{a}_\mathrm{j}$ are regarded as indifferent. To make it possible, the concepts of a semi-criterion and pseudo-criterion are introduced (see, for instance, Roy[3] , Roy and Vincke[4], and Vinck[21]): For each criterion g_k :

(1) by introducing only an indifference threshold q_k, strict preference P and indifference I are defined as:

$$\mathbf{a}_\mathrm{i} P \mathbf{a}_\mathrm{j} \text{ if and only if } g_k(\mathbf{a}_\mathrm{i}) - g_k(\mathbf{a}_\mathrm{j}) \geq q_k,$$

$$\mathbf{a}_\mathrm{i} I \mathbf{a}_\mathrm{j} \text{ if and only if } \left|g_k(\mathbf{a}_\mathrm{i}) - g_k(\mathbf{a}_\mathrm{j})\right| \leq q_k.$$

The underlying preference structure is called a semi-order structure and g_k is called a semi-criterion.

(2) in order to avoid an abrupt change from strict preference to indifference as in (1), two thresholds, an indifference threshold q_k and a preference threshold p_k, are introduced: When the positive difference $g_k(\mathbf{a}_\mathrm{i}) - g_k(\mathbf{a}_\mathrm{j})$ is sufficiently small, that is, $g_k(\mathbf{a}_\mathrm{i}) - g_k(\mathbf{a}_\mathrm{j}) \leq q_k$, $\mathbf{a}_\mathrm{i}$ and $\mathbf{a}_\mathrm{j}$ are considered indifferent. To have a strict preference, it is necessary that the positive difference $g_k(\mathbf{a}_\mathrm{i}) - g_k(\mathbf{a}_\mathrm{j})$ be sufficiently large, that is, $g_k(\mathbf{a}_\mathrm{i}) - g_k(\mathbf{a}_\mathrm{j}) > p_k$. The case where

$q_k < g_k(\mathbf{a}_i) - g_k(\mathbf{a}_j) \le p_k$ is interpreted as a hesitation between indifference and strict preference, being sure that not $\mathbf{a}_j P \mathbf{a}_i$. It is called a weak preference. This concept allows us to apprehend the ambiguity inherent in the presence of imprecision, uncertainty, or indetermination (see, Roy[17])
The underlying preference structure is called a pseudo-order structure and g_k is called a pseudo-criterion. A pseudo-order structure includes a semi-order structure as a special case where $p_k = q_k$.

In the outranking relation method, for each pseudo-criterion g_k, a mono-criterion outranking relation $c_k(\mathbf{a}_i, \mathbf{a}_j)$ is defined as follows:

(i) Strict preference $\mathbf{a}_i P \mathbf{a}_j$: If $g_k(\mathbf{a}_i) - g_k(\mathbf{a}_j) \ge p_k$ then $c_k(\mathbf{a}_i, \mathbf{a}_j) = 1$ and $c_k(\mathbf{a}_j, \mathbf{a}_i) = 0$

(ii) Weak preference $\mathbf{a}_i W \mathbf{a}_j$: If $q_k < g_k(\mathbf{a}_i) - g_k(\mathbf{a}_j) \le p_k$ then $c_k(\mathbf{a}_i, \mathbf{a}_j) = 1$ and $0 < c_k(\mathbf{a}_j, \mathbf{a}_i) < 1$

(iii) Indifference $\mathbf{a}_i I \mathbf{a}_j$: If $|g_k(\mathbf{a}_i) - g_k(\mathbf{a}_j)| \le q_k$ then $c_k(\mathbf{a}_i, \mathbf{a}_j) = 1$ and $c_k(\mathbf{a}_j, \mathbf{a}_i) = 1$.

Using the weights $W = \{w_k\}$, the concordance index $C(\mathbf{a}_i, \mathbf{a}_j)$ is defined as follows:

$$C(\mathbf{a}_i, \mathbf{a}_j) = \sum \boldsymbol{w_k c_k}(\mathbf{a_i}, \mathbf{a_j}) \; w_k \quad c_k(\mathbf{a}_i, \mathbf{a}_j)$$

On the other hand, by introducing a veto threshold v_k for each criterion g_k, a discordance index $d_k(\mathbf{a}_i, \mathbf{a}_j)$ that rejects the assertion $\mathbf{a}_i$ outranks $\mathbf{a}_j$ is defined:

(i) If $g_k(\mathbf{a}_j) - g_k(\mathbf{a}_i) \le p_k$, then $d_k(\mathbf{a}_i, \mathbf{a}_j) = 0$.

(ii) If $p_k < g_k(\mathbf{a}_j) - g_k(\mathbf{a}_i) \le v_k$, then $0 < d_k(\mathbf{a}_i, \mathbf{a}_j) < 1$.

(iii) If $g_k(\mathbf{a}_j) - g_k(\mathbf{a}_i) > v_k$, then $d_k(\mathbf{a}_i, \mathbf{a}_j) = 1$.

Using the concordance and discordance indices, a comprehensive outranking relation $\mu(\mathbf{a}_i, \mathbf{a}_j)$ is defined by:

$$\mu(\mathbf{a}_i, \mathbf{a}_j) = \begin{cases} C(\mathbf{a}_i, \mathbf{a}_j) \Pi_{k \in \{k : d_k(\mathbf{a}_i, \mathbf{a}_j) > C(\mathbf{a}_i, \mathbf{a}_j)\}} \dfrac{1 - d_k(\mathbf{a}_i, \mathbf{a}_j)}{1 - C(\mathbf{a}_i, \mathbf{a}_j)} & \\ C(\mathbf{a}_i, \mathbf{a}_j) & \text{if } d_k(\mathbf{a}_i, \mathbf{a}_j) \le C(\mathbf{a}_i, \mathbf{a}_j) \text{ for all } k. \end{cases}$$

In the final stage, the distillation method using a discrimination threshold function is used to rank alternatives in descending and ascending orders.

3. Supply Chain Network Reconfiguration Problem

The business entity has many warehouses and agents generally in the every corner. There is a long demand chains of the business entity's products consisting of construction dealers, agents, business offices, enterprises, and plants / factories. The distribution process of the business entity is illustrated in Figure 2. As shown in Figure 2, logistics network of the business entity is one-stage distribution system, where the warehouses are supplied from factory. Such as the business entity has 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. In some cases the business entity has a problem, how many warehouses are needed.

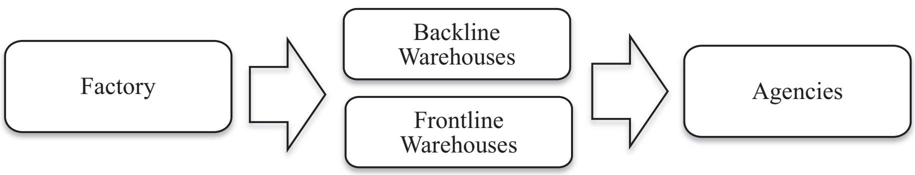

Figure 2. Business entity's distribution process

Problem Formulation

Three strategies have different inventory and distribution systems. Therefore, they can be subdivided into 6 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).
- Customers in North-East region will receive the products in one day (the following day) from the 'Kanto' warehouse.

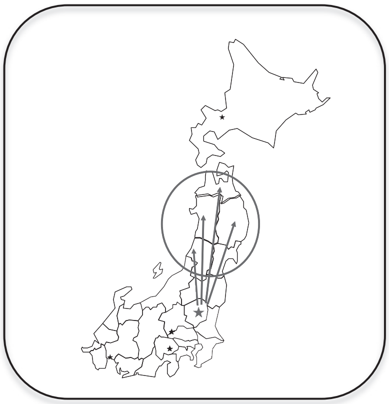

Figure 3. Alternative 1

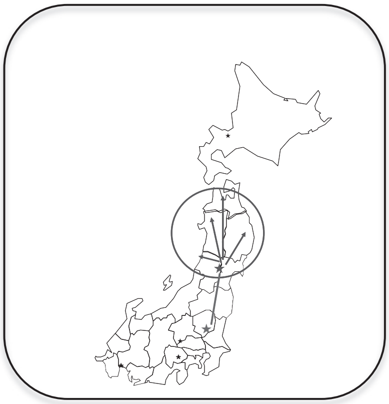

Figure 4. Alternatives 2, 3 and 4.

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 25% of all items will be stocked/stored for one day delivery.
- the rest will be delivered from 'Kanto' warehouse in 2 days

Alternative 3 (a variant of the status quo) (see Figure 4):

- the frontline warehouse in the North-East region is not merged and 50% of all items will be stocked/stored for one day delivery.
- the rest will be delivered from 'Kanto' warehouse in 2 days

Alternative 4 (a variant of the status quo) (see Figure 4):

- the frontline warehouse in the North-East region is not merged and 80% of all items will be stocked/stored for one day delivery.
- the rest will be delivered from 'Kanto' warehouse in 2 days

Alternative 5 (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 5

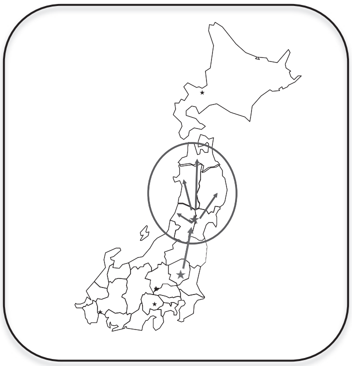

Figure 6. Alternative 6

Alternative 6 (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, while some receive one day delivery service, others 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, because it is difficult to estimate precisely cost value due to time and cost constraints. Therefore, we have decided to look at all these costs separately. We use the following scores:

Significant reduction compared to the status quo	7
Some reduction compared to the status quo	6
A little reduction or almost same	5
Same as the status quo	4
Almost equal to the status quo or higher	3
Higher than the status quo	2
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 and in order to convert this into maximization criterion,
We can get the inventory score as follows:

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

Based on the above criterion, the scores are as below:

Alternatives /Criteria	Distribution cost	Handling cost	Storage cost
Alt 1	1	7	7
Alt 2	4	4	4
Alt 3	4	3	3
Alt 4	4	2	3
Alt 5	2	5	7
Alt 6	3	5	7

Inventory (ten million yen)	No. of items delivered in one-day	No. of regions delivered in one-day	Competitive Advantage
6.7	9685	2	1
6.2	2452	1	3
5.7	4904	1	3
5.1	7846	1	3
6.7	9685	2	2
6.7	9685	1	2

We employ the outranking ELECTRE lll method. Therefore, it is important to determine the preference (P), indifference (Q) and veto (V) thresholds.

1. For costs, we set, P=2, Q=1 and V=7.
2. For inventory, the thresholds are as follow: P=0.3, Q= 0.1 and V=3
3. For the number of items delivered in one day, we set P=1,000, Q= 500, and V=8,000.
4. For the number of regions delivered in one day, we set P=1, Q= 0, and V=3.
5. For competitive advantage, P=1, Q= 0, and V=3

We set the equal weights for seven criteria. In the distillation method, a discrimination threshold function is usually set at the following:

$$s(\lambda) = 0.3 - 0.15\lambda$$

Thus, we have a final ranking; Alt. 6 >>Alt. 1 >> Alt. 5>> Alt. 2 >> Alt. 3 >> Alt. 4.

4. AHP Approach with GA

In this paper, we utilized a matrix-form coding method to control lethal gene in GA process. GA suggests the warehouse to be left including decision maker’s opinions. We utilized a simple AHP and matrix-form coding method to control lethal gene in GA process. The Process is the first, AHP is utilized to get the weight of decision maker’s then the weight is used in GA process [5].

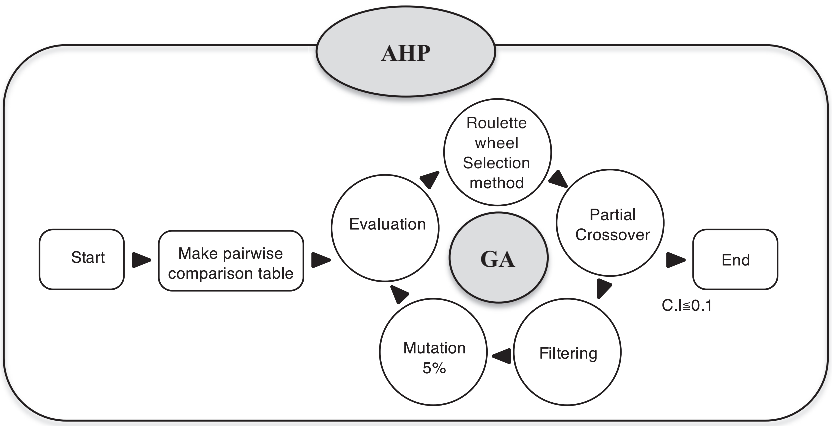

Figure 7. AHP with GA

In this process, GA contributes to control the value of consistency index.

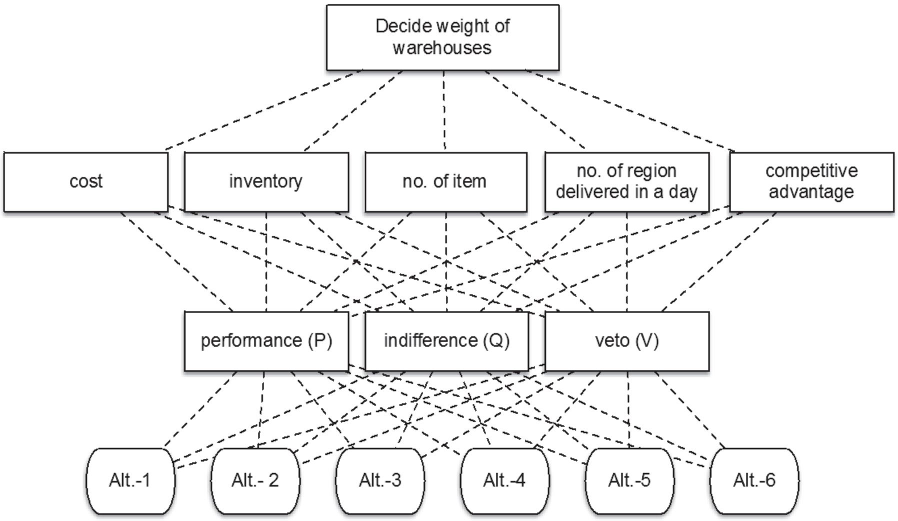

Figure 8. A Hierarchical tree in AHP approach

Finally, The results from all process are summarized in below Table 2.
We performed numerical experiments according to designed AHP-hierarchy in Figure 8. The total evaluation results form AHP is shown in below Table 2.

Table 2. Total Evaluation of AHP with GA

Criteria (upper level)		Criteria (lower level)		Alternatives					
	Weight		Weight	Alt-1	Alt-2	Alt-3	Alt-4	Alt-5	Alt-6
cost	0.28	performance (P)	0.39	0.21	0.18	0.16	0.03	0.19	0.23
inventory	0.17			0.14	0.09	0.13	0.16	0.22	0.26
no. of item	0.14	indiffernce (Q)	0.32	0.16	0.19	0.11	0.18	0.21	0.15
no. of delivery	0.23			0.11	0.14	0.13	0.17	0.23	0.22
competitive	0.18	veto (V)	0.29	0.15	0.13	0.19	0.11	0.23	0.19
Total Weight	1.0000		1.0000	0.1573	0.1479	0.1464	0.1197	0.2143	0.2144

From GA-AHP approach, we can find a rank: Alt.-6 >> Alt.-5 >> Alt.-1 >> Alt.-2 >> Alt.-4.

A GA contains 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 [5] and then set up as Table 5.. Validation of an analytical method through a series of experiments demonstrates that the method is suitable for its intended purpose.

5. Concluding remarks

Both ELECTRE-lll method and GA-AHP proposed the same results that the best alternative is Alt. 6. But, the second priority is that ELECTRE-lll method proposes Alt.-1 then Alt.-5, GA-AHP proposes Alt.-5 then Alt.-1. These alternatives indicate that the warehouse in the North East region to be merged (non-operating, or operating as a depot). Alternatives 2, 3 and 4 signify non-merging alternatives. Alt. 3 (which increases a little the number of items to be stored compared with the status quo) and Alt. 4 (which significantly increases the number of items to be stored compared with the status quo) are as good as the status quo. These results are consistent with the manager's experience and intuition.

Even if the result of alternatives do not seem to provide enough insight on decision making, by carrying out a AHP 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. It suggests that, in this case, AHP method is useful.

In this research, a Supply chain Network model has been proposed using Outranking Analysis & GA-AHP method. These approaches were used to synthesize the opinions of the decision makers to identify the weight of each alternative. This research demonstrated the advantage of being able to capture decision maker's opinion and intuition in solving the research problem through a structured manner and a simple process.

Further development of this approach could be the improvement in the determination of the weights of each alternative and to handle uncertainty level of the decision-making problem by using hybrid approach, like the ANP, Neural Network, and so on.

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