The Application of AHP in Location Selection of Logistics Enterprises: Based on China YY Logistics Company

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ABSTRACT: Site selection is a critical decision for a company in today's competitive environment. The proper decision of business line will bring many benefits to the company. When it comes to site selection, the impacts of each criterion may be different, and these impacts may conflict with each other. As a result, it can be clearly noted that the location issue of the logistics company is a very complicated structure, including some issues such as profitability, running cost reduction, durability and efficiency improvement. In order to achieve above goals issues, logistics companies must consider relevant standards and use convenient ways to choose their own location. As a result, all aspects must be taken into account in solving this issue. In this study, it mainly solved the issue of location selection for a new logistics company. Since this issue involves both invisible and explicit criteria, the AHP is considered to be the main way.

Keywords: Analytic Hierarchy Process; Location Selection; Logistics

1 INTRODUCTION

Logistics plays a key role in today's business development. The development of logistics is to give the company a competitive advantage in terms of cost and time. This is the most important factor in competitiveness. This is especially true for industrial enterprise logistics covering all activities related to the internal flow of materials within the company. These activities include material flows from suppliers, warehouses, logistics of production packages, exploration and distribution to suppliers. It also includes materials and goods for transporting the above activities. Logistics can be understood as a way to manage these activities, greatly improving business efficiency.

In general, the siting issue points to the identification of specific areas for facility deployment [1]. Choosing a specific location based on market nature will directly affect the company's competitiveness and performance, so it is a strategically significant decision issue. From this case, the management capacity to solve this critical issue will provide stability in the above-mentioned competitive environment, but the exact choice of location will mainly ensure that enough products are available at anywhere and anytime [2]. The good location not only attracted customers, but also increased the sales volume in this very competitive commercial world. In addition, as an important decision, mistakes made during this period could lead to too much excessive transportation fees, loss of professional workers and expected benefits, which may undermine administrative issues [3]. As a result, we can see clearly that an appropriate choice should achieve the company's goals. To do so, these requirements have to be fully and objectively identified. Besides, decision-makers must also take a long time to determine the criteria that influence the choice [4]. Like all practical issues, the issue of location selection presents a complex structure containing invisible and explicit factors. As a result, a variety of multi-standard decision-making ways have been utilised in AHP, network analysis, TOPSIS, and other ways, including integrated ways [5]. In this study, it solves the practical issue of logistics company location selection. This is a multi-standard decision issue that includes invisible and explicit factors [6], so AHP way is chosen to solve this issue.

This study consists of five parts: the first part briefly introduces the issue of location selection. The second part explains AHP way. The third part discusses the application of AHP. In the next part, the issue of logistics company location selection and its AHP model will be given. And the result of the evaluation forms the final part.

2 THE METHOD OF AHP

Analytic hierarchy process (AHP) is one of the multi-standard decision making ways originally developed by Professor Thomas L. Saaty [7]. In other words, it is a way to derive scaling from comparisons. Input can be obtained from actual measurements such as price and weight. It can also be obtained from subjective opinions such as satisfaction and preference [8]. Analytic hierarchy process allows some small judgments to be inconsistent, because human beings are not always consistent. The scale is derived from the main eigenvectors, and the consistency index is derived from the main eigenvalues

[9].

Analytic hierarchy process (AHP) is a structured, measuring and integrating wayology [10]. Analytic hierarchy process (AHP) is applied to a variety of issues: selecting alternatives to compete in a multi-purpose environment, allocate scarce resources and make predictions [11]. Although AHP's axioms have broad applicability, they carefully define the scope of the problem environment [12]. This generates actual or approximate weights based on this explicit mathematical structure from the uniform matrix and its associating right eigenvectors [13].

AHP is primarily used to solve selection issues in multi-standard environments. In this pattern, the approach includes comparing goals and alternatives in a natural, paired way [14]. The AHP converts different preference into proportional scale weight, which combines them with linear additional weight of relevant alternatives [15]. These weights are used to replace the ranking to help decision makers (DM) make choices or predict results. The AHP takes three mutually agreed decision steps: (1) Assuming i = 1, ..., m targets and determining their respective weights wi, (2) For every target i, j = 1, ..., n As a comparison alternative, determine their weight wij target i and (3) determine the final (global) replacement weight (priority) Wj of all targets by Wj = w1jw1 + w2jw2 + ... + wmjwm after that, these alternatives are ordered by Wj and the most preferred alternative has the largest Wj. Different decision-making methods (AHP, Electrore, multi-attribute utility theory) are distinguished by target decision methods and permutation weights, as defined by every axiom or rule-based structure. AHP's simple validity and confidence in the ability to handle multi-purpose decisions is based on hundreds of (and currently thousands) different applications where AHP results are accepted and used by cognitive DM [16].

Understanding the three main functions of AHP-complexity building, measurement, and synthesis-helps you understand the reason that AHP should be considered a universal approach that can be used to a wide range of applications [17].

2.1 Building complexity

Saaty is looking for an easy way to handle complexity. And he has found a common theme about how humans deal with complexity and stratified complexity into a uniform cluster of factors. Others have recognized the significance of hierarchical structure as well[18].

2.2 Measurement on a ratio scale

According to Stevens (1946), there are four measuring scales. The lowest to the highest ranges of attributes are nominal, ordinal, interval and ratio. Each level has attributes of all levels above, including meaning and statistics, as well as other attributes [19]. For example, ratio measurements have ratio, interval, ordinal number and nominal attribute. Interval metrics have no ratio attributes, but they have intervals, ordinal and nominal attributes [20]. Ratio measurement is a necessary condition for scaling and is the basis of physical measurement. This understanding, in addition to the need for a mathematically correct, axiomatic approach, makes the article deduce (rather than allocate) by using a hierarchical factor of comparative way (rather than distribution), and can be interpreted as a final sort of measure (weight) than a scale [21]. Any level-based way must use the ratio level priority of elements over the one of lowest level. It is necessary that the priority (or weight) of any level of Elements in the hierarchy are determined by multiplying the priority of the elements in the element by the priority of the parent element. This is because the product of two interval measurements is mathematically meaningless, this multiplication needs scale calibration. Because, unlike many ways, AHP takes advantage of scale or even the lowest level (in the choice of alternatives of the model), the resulting emphasis on the selection of the analytic hierarchy model will be more than the measure of scale [22]. This is especially significant when priority is given not only to application selection, but also to other types of applications such as resource allocation and forecasting.

2.3 Synthesis

Analytic way is the first word in the name of AHP, which means separating an entity or **Abstract:**entity into its constituent parts. [23]. On the contrary, synthesis involves combine parts into one. Complex decision making or prediction or resource allocation often involves too many factors that make human beings unable to intuitively synthesize. Requirements are a comprehensive approach in many ways. Although the hierarchy of AHP does contribute to analysis, as well as an important function is ability of analytic hierarchy process to measure and integrate many factors in a hierarchical structure [24]. In addition, we know that there is no other way to promote synthesis, just like analytic hierarchy process.

In summary, AHP is a common measurement theory used to derive scale scales from alternative and standard discrete and continuous pair-wise comparisons in a multi-layered structure. In order to measure attribute weights using AHP, the decision maker performs a series of pairwise comparison decisions in 9 stages (1 / 9, 1 / 7, 1 / 5, 1 / 3, 1, 3), 5, 7, 9), The relative importance of attributes to appropriate targets. For example, for three attributes, export the ratio of wa / wb, wa / wc, wb / wc. If attribute a has the same importance as attribute b, the ratio wa / wb is defined as 1. If the attribute a is much more important than the attribute b, the ratio is specified as 9 and if attribute a is much more important than attribute b, the ratio is 1/9. AHP weights and values are not clearly distinguished. Attribute weights and alternative values are derived from pair-wise comparisons. The following steps are related to AHP. (1) Decision makers / stakeholders need to compare the relative importance of criteria in pairs. (2) Standard weights are calculated from pair-wise comparisons as feature vectors corresponding to matrix feature values. (3) Normalize the feature vector to a maximum of 1. (4) Repeat steps 1 to 3

to compare options. (5) Finally, calculate the total score for each choice using the following formula:

$$a_j = \sum_{i=1}^{n} w_i \alpha_{ji} \quad (1)$$

In which wi = weight of criterion i; αji = Score of alternative j with respect to criteria i; n = Number of criteria; aj = Overall score of alternative j. Alternative j score for criterion i. n = number of criteria. aj = Total score of alternative j. (6) Perform a sensitivity analysis and select the alternative (the highest score). (7) The entire analysis reporting.

3 THE APPLICATION OF AHP

In 1976, AHP is a multi-standard decision making way cultivated by Saaty. Due to its outstanding advantages, this way has been successfully applied in diverse aspects. As i mentioned earlier, this way considers both invisible and explicit factors, and this one

is consistent with the subjective characteristics of real world issues. In addition, a hierarchical structure containing multiple time periods, making decision and standards could be called another advantage. However, the hierarchical model helps decision makers participate in the solution process and reevaluate judgments as necessary. As a result, policymakers can also provide mutual agreement before final decision [25].

Even if there are differences in each study, the AHP has four general steps at its core. First, alternatives, primary and secondary criteria ought to be identified.The next step is hierarchical modeling of decision-making issues, taking into account previously selected criteria [26]. Decision-maker decisions are collected through a third-stage pair-wise comparison. [27]. This step determines the significance of alternatives and standards by analyzing and comparing the data inside. As a result, it is necessary to compare these standards with alternatives.

During this process, Saaty's relative importance scale will be used [28], ranging from 1 to 9. The ratio is given in Table 1 below.

Table 1. Fundamental scale used in AHP

Intensity of Importance	Definition	Explanation
1	Equally Important	Two activities contributing in the same way to the objective
2	Weak	--
3	Moderate Importance	Experience and judgment are slightly biased towards other activities
4	Medium Plus	--
5	Very Important	Experience and judgment support activities are stronger than others
6	Strong Plus	--
7	Very Plus	One activity takes precedence over other activities
8	Very strong	--
9	Extremely Important	Evidence supporting one activity over another may have the highest positive order

We can be see from Table 1 that the ranking ought to be as follows: 1 is equally important, 3 is medium, 5 is strong, and 7 is very important.If anyone element from the comparison is more significant than the other, you need to give 9 points. If the decision maker is hesitate facing two values, other options can be used. From these comparisons, a pairwise comparison matrix is obtained.

The next step is to calculate the ratio of inconsistency for each matrix. These ratios can determine the possible error assessments in the comparison. Overall, 0.10 is the extremely limit of the one, while some scholars can accept this ratio becoming 0.20. This process continues if all matrices are guaranteed to be consistent. Otherwise, pairwise comparisons have to be repeated to make inconsistent pairwise comparisons until the ratio within the limits is provided.

The determination of the relative importance level based on judgment can be defined as the steps followed. The synthesis of the results and the choice of the best choice provide a way for the final step.

4 APPLICATION OF AHP IN LOGISTICS COMPANY LOCATION SELECTION

We consider China YY Logistics Company, which provides services to more than 120 countries each year. Owned by Chinese government, the company operates in more than 30 countries, serves 22 million customers, and owns other brands. After deciding to open a new logistics company, YY Company recently faced location issues. As an important strategic decision, it should include both invisible and explicit criteria. Therefore, in order to tackle this issue, the AHP way is considered as a method. From the first step procedure alternative, the primary and secondary criteria were identified. After several interviews, three locations were identified and renamed L1, L2, L3, L4, L5 and L6 due to the company's privacy policy.

Based on the different advantages of these locations, more than 40 standards were proposed, five of which were standard; industry factors, environmental factors, investment costs, labor force, and regional strength are selected as the major criteria.

The first two and last major criteria define different sub-criteria as follows:

-Sectoral factors: Near Market (NM), Regional Business Activity (RCA), Customer Potential (CP), Subjective Factor (SF), Competitor Availability (AC);

-Environmental reasons:Transport, climate change, urbanization rate, land resources, safety

-Regional potential: Number of big companies in the area (NC), Area ratio of logistic service (ALS);

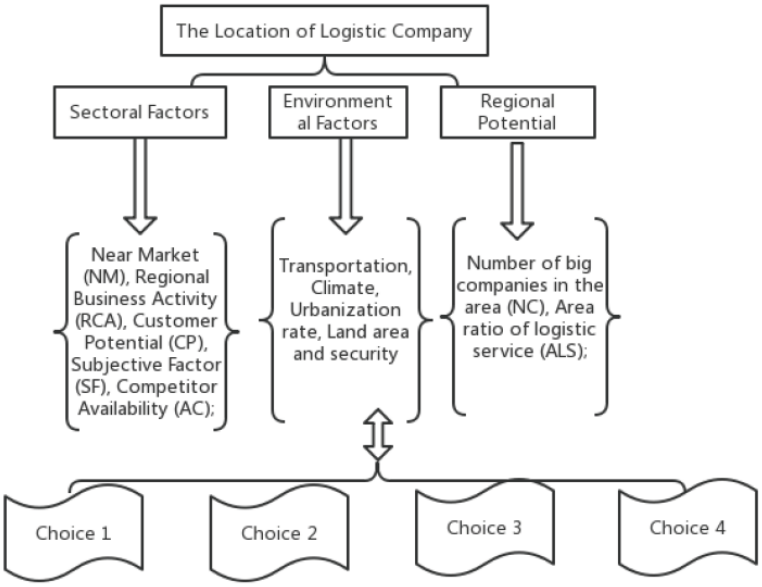

Figure 1. The detail of factors

After modeling decision issues Collect data from decision making as above through pairwise comparisons. Using the scale shown in Table 1, a pairwise comparison matrix is obtained. Table 2 shows an example of these matrices, including evaluations of senior managers.

Table 2. Pairwise comparison matrix of the major criteria

	Sectoral Factors	Environmental Factors	Investment Cost	Labor Cost	Regional Potential
Sectoral Factors	1	6	7	7	1/7
Environmental Factors	1/6	1	13	1/3	1/7
Investment Cost	1/7	3	1	2	1/5
Labor Cost	1/7	3	2	1	1/4
Regional Potential	7	7	5	4	1

According to this matrix, sectoral factors are of great significance compared to environmental reasons and are of great significance to investment costs and workers' potential. Regional potential can be seen as the most significant element in the major criteria.After all matrices were acquired, inconsistency ratio was detected and all ratios were between 0 and 0.09. These results are less than 0.10,

o it is clear that all matrices are consistent. The AHP analysis step solves the problem by calculating the relative weights of all choices and criteria. We can see it clearly that all matrices are also consistent. Tthe AHPanalysis program, calculating the relative weights of all alternatives and standards can solve the issue. In oerder to achieve this result, expert selection 11 wass used, and the relative weights of the criteria are shown in Table 3 below.

Table 3: Relative weights of main and sub-criteria

Criteria	Relative Weights
Departmental factor	0.187
-Market proximity	0.623
-Local business activities	0.573
-Customer potential	0.217
-Subjective factors	0.127
-Competitive availability	0.056
Environmental Factors	0.176
-Transportation	0.145
-Climate	0.268
-Urbanization rate	0.364
-Land size	0.212
-Security	0.189
Investment Cost	0.184
Labor Potential	0.057
Regional Potential	0.468
-Number of big companies in the area	0.148
-Area ratio of logistic service	0.378

From Table 3, we can see that regional potential standards are the most significant criteria for the location of YY Company. Then there are sectoral reasons, investment costs, working potential and environmental factors. The team will approve these results and their validity before selecting a location. As a result, the significance of this key criteria is calculated and shown in Table 4.

As can be seen from Table 4, the best location is L1. The execution of this result is the final step of it.

We also do CI test, the formula is:

$$CI = \frac{l_{\max} - n}{n - 1} \tag{2}$$

Table 4. Importance values and alternative ranking.

Alternatives	Importance	Ranking

L1	0.794	1
L2	0.106	2
L3	0.027	3
L4	0.018	4
L5	0.016	5
L6	0.007	6

According to this formula, we could get the following results (Table 5), where CI = 0.02, which means our results are reliable.

Table 5. The results of RI

Dimensional	1	2	3	4	5	6	7	8	9
RI	0.00	0.00	0.58	0.96	1.12	1.24	1.32	1.41	1.45

5 DISCUSSIONS AND CONCLUSIONS

In today's competitive environment, how to select a site selection is a critical decision of the company. The proper decision of business line will bring many benefits to the company. In the case of site selection, the impact of each criterion may be different, and these effects may conflict with others [29]. Therefore, these issues show a complicated structure composed of invisible and explicit factors, so it can be said that AHP is a easy way to tackle these issues. From this study, the location of YY Company was addressed [30]. This issue was modeled above and the pairwise comparison matrix was obtained accordingly. Calculate the inconsistency ratio and ensure that all matrices were consistent after obtaining the relative weights. In Table 2, these figures indicated that regional potential was the most important of these. As a result, the importance level of alternatives was calculated, and we can select L1 region as the best location for this issue according to Table 4.

Since this research is conducted within a specific business scope, the standard is based on the logistic industry, so this situation could be thought as the limit of the study [31]. However, this hierarchical model built for this issue can provide insight into the location selection issue. In addition, as an example of a viable approach to solving real problems, this article can guide companies and researchers that could be involved in this kind of problems in the near future. [32].

References

[1] D.E. Bell, H. Raiffa, and A. Tversky. Decision Making: Descriptive, Normative, and Prescriptive Interactions. Cambridge University Press: Cambridge, England, 1988.

[2] D.E. Bell, R.L. Keeney, and H. Raiffa. Conflicting Objectives in Decisions. John Wiley and Sons: NY, USA, 1977.

[3] V. Belton and T. Gear. On a Shortcoming of Saaty's Method of Analytic Hierarchies. Omega, 1982, 11(3): 226-230.

[4] V. Chankong and Y.Y. Haimes. Multiobjective Decision Making, North-Holland, NY, 1983.

[5] D.M. Buede and D.T. Maxwell. Rank Disagreement: A Comparison of Multi-Criteria Methodologies. Journal of Multi-Criteria Decision Analysis, 1995, 4(1): 1-21.

[6] C.W. Churchman. Measurement for Management Decision: A Perspective. California Management Review, 1979, 21(3): 14.

[7] R. Corbin and A. A. J. Marley. Random Utility Models with Equality: An Apparent, but not Actual, Generalization of Random Utility Models, Journal of Mathematical Psychology, 1974, 11: 274-293.

[8] R.M. Cyert, H.A. Simon, and D.B. Trow. Observations of a Business Decision. Journal of Business, University of Chicago, 1956, 29: 237-248.

[9] J.S. Dyer. Remarks on the Analytic Hierarchy Process. Management Science, 1990, 36(3): 249-258.

[10] H.G. Eyrich. Benchmarking to Become the Best of Breed. Manufacturing Systems Magazine, 1991 April.

[11] P.C. Fishburn. Nontransitive Preferences in Decision Theory. Journal of Risk and Uncertainty, 1991, 4: 113-134.

[12] G.S. Fishman and P.J. Kiviat. Digital Computer Simulation: Statistical Considerations, RM-5387-PR, The RAND Corp., Santa Monica, Calif., 1967 (Also published as: The Statistics of Discrete Event Simulation, Simulation, April 1968).

[13] E.H. Forman. Relative vs. Absolute Worth. Mathematical Modeling, 1987, 9(3-5): 195-202.

[14] E.H. Forman. AHP is Intended for More than Expected Value Calculations. Decision Sciences, 1990, 21(3): 670-672.

[15] E.H. Forman. Deriving Ratio Level Measures from Verbal Judgments. George Washington University Working Paper, 1990.

[16] S.I. Gass. Decision-Aiding Models: Validation, Assessment, and Related Issues for Policy Analysis. Operations Research, 1983, 31(4): 603-631.

[17] S.I. Gass, 1998. Tournaments, Transitivity and Pairwise Comparison Matrices. Operational Research, 1998, 49(6): 616-624.

[18] P.T. Harker. Incomplete Pairwise Comparisons in the Analytic Hierarchy Process. Math Modeling, 1987, 9(11): 837-848.

[19] J. Huber and C. Puto. Market Boundaries and Product Choice: Illustrating Attraction and Substitution Effects. Journal of Consumer Research, 1983, 10: 31-44.

[20] J. Huber, J.W. Payne, and C. Puto. Adding Asymmetrically Dominated Alternatives: Violations of Regularity and the Similarity Hypothesis. Journal of Consumer Research, 1982, 9: 90-98.

[21] C.-L. Hwang and K. Yoon. Multiple Attribute Decision Making. Springer-Verlag: NY, USA, 1981.

[22] R.L. Keeney and H. Raiffa. Decisions with Multiple Objectives: Preference and Value Tradeoffs. John Wiley & Sons: NY, USA, 1976

[23] C. Kirkwood. Strategic Decision Making–Multiobjective Decision Analysis with Spreadsheets. Duxbury Press: Belmont CA, 1997.

[24] Thomas S. Kuhn. The Structure of Scientific Revolution. University of Chicago Press, 1962.

[25] Henry M. Levin. Cost-Effectiveness, A Primer New Perspectives in Evaluation, Volume 4, Sage Publications, Beverly Hills, CA, 1983, p.121.

[26] R.D. Luce and H. Raiffa. Games and Decisions. John Wiley and Sons, Inc.: New York, USA, 1957.

[27] J. Milnor. Games Against Nature, pp. 49-60 in Decision Processes, R.M. Thrall, C.H. Coombs, and R.L. Davis (eds.), John Wiley & Sons, NY, 1954.

[28] M.J. Osborne and A. Rubinstein. A Course in Game Theory. M.I.T. Press: Cambridge, Mass, 1994.

[29] V.M. Ozernoi and M.G. Gaft. Multicriterion Decision

Problems, pp. 17-39 in Conflicting Objectives in Decisions, D.E. Bell, R.L. Keeney, and H. Raiffa (eds.), John Wiley and Sons, NY, 1977.
[30] T.L. Saaty. Axiomatic Foundation of the Analytic Hierarchy Process. Management Science, 1986, 32: 841-855.
[31] T.L. Saaty. Rank and the Controversy About the Axioms of Utility Theory -- A Comparison of AHP and MAUT, Proceedings of the 2nd International Symposium of The Analytic Hierarchy Process, Pittsburgh, PA, 1991, 87-111.
[32] B.S. Schoner and B.W. Wedley. Ambiguous Criteria Weights in AHP: Consequences and Solutions. Decision Sciences, 1989, 20: 462-475.