Selection of material supplier in job shop environment: The extent analysis on fuzzy stochastic AHP

Jirapat Wanitwattanakosol *, Apichat Sopadang

Department of Industrial Engineering, Faculty of Engineering, Chiang Mai University

239 Huay Kaew Road Muang District Chiang Mai 50200

Tel 0-5394-4183 Fax 0-5394-4185 E-mail *g510651013@cm.edu, apichat@chiangmai.ac.th

Abstract

With the increasing significant effect of supply chain management, once a supplier becomes part of a well-managed and established supply chain, it will have a lasting effect on the competitiveness of the entire supply chain. As organizations become more dependent on suppliers, for this reason the direct and indirect consequences of poor decision making become more severe. However, the selection of a suitable partner is not an easy decision and is associated with uncertainty and complexity. For this reason, the aim of this research is to propose a multi criteria decision making (MCDM) approach to effectively select material alliance suppliers. The proposed methodology consists of three parts: (i) preliminary screening of available suppliers, (ii) the extent analysis method on fuzzy AHP to rank the alternatives (iii) the fuzzy stochastic AHP is presented to capture the best alternative(s) with certain confidence. The final selection of a material supplier in job shop environments is demonstrated through an illustrative example. This approach, also enables to gain insight into how the imprecision in judgment ratios may affect their alternatives toward the best solution, may subsequently improve the reliability of the decision.

Keywords: Job shop environment; Fuzzy AHP; Extent analysis; Simulation

1. Introduction

The effect of supply chain management (SCM) has spread in many fields of industry sector such as electronics [23], telecommunication [21], and also automobile [22]. Mason et al., (2002) asserted a growing recognition of supply chains that individual business which previously competed as stand-alone entity is now establishment in the form of network relationships and competing as supply chains. The intense global competition forces manufacturers who seek to respond their customers with high quality products in the right time at the right place [1]. Hence, one of the critical challenges for managing supply chain is the selection of strategic partners that will furnish them with the necessary products, components and materials in a timely and effective manner to help maintain a competitive advantage [19].

Strategic alliance is an important part for the organizations to concentrate only on their core competencies, cost reduction, improvement of services and efficient operations, etc [10]. The proliferation of strategic alliance has been increasing in the last decade across supply chains paradigm [3]. This study focuses on the supplier selection because a supplier becomes part of a well-managed and established supply chain. It will have a lasting effect on the competitiveness of the entire supply chain. As organizations become more dependent on suppliers, for this reason the direct and indirect consequences of poor decision making become more severe.

The problem to select qualified supplier is increasing complex for decision maker (DM). In addition, from the subjective considerations are relevant to partner evaluation and selection decision. Multi criteria decision making (MCDM) is a popular technique to deal with imprecision in supplier choice [6]. However, in real life the available information in a MCDM process is usually uncertain, vague, or imprecise, and the criteria are not necessarily independent. To handle the vagueness in information and the essential fuzziness of human judgment/preference, fuzzy set theory was proposed by Zadeh, (1965).

SMEs are considered as a vital component of Thai's economics fundamental. Anyway, many SMEs are vulnerable in that they operate in sectors where they have little power to dictate to suppliers their needs [2]. The lower volumes make it difficult to develop the most profitable partnerships with supplier in terms of delivery quantity, frequency and price [11]. To relieve this disadvantage, SMEs have to use the strategic management as supplier selection that has an important strategic outcome to achieve superior competitive advantage.

For this reason, the aim of this research is to propose MCDM approach to effectively select material alliance suppliers. The proposed methodology consists of three parts: (i) preliminary screening of available suppliers, (ii) the extent analysis method on fuzzy AHP to rank the alternatives (iii) the fuzzy stochastic AHP is presented to capture the best alternative(s) with certain confidence. The final selection of a material supplier in job shop environment is demonstrated through an illustrative example. This approach enables to gain insight into how the imprecision in judgment ratios may affect their alternatives toward the best solution, and also may subsequently improve the reliability of the decision.

The remainder of this paper is then organized as follows. Section 2 discusses the related literatures on supplier selection and decision tools. The literature review includes selection criteria for the supplier, decision tools for using in this research such as conjunctive and disjunctive method, fuzzy analytical hierarchy process etc. Section 3 presents a research framework and describes the procedures of this model. Section 4, an empirical study is given to demonstrate the potential of the methodology. Results and discussion of the proposed framework are mentioned and analyzed in section 5. Finally, conclusions and further research directions are provided in section 6.

2. Literature Review

The literature review is mainly aimed at indication of the criteria that need to be considered in supplier selection. In this section, fuzzy AHP, extent analysis method and a stochastic approach for AHP are also briefly described as follows. The outcome of literature review has been used to (i) create a framework that will use in short-listing the suppliers, and (ii) develop an extent analysis method on fuzzy AHP model for final selection procedure of a supplier.

2.1. Criteria for the selection of a supplier

Purchasing department, plays an important role for success or failure of the company in the supply chains paradigm, has to select the suitable suppliers. To obtain a competitive advantage, the company is streamlining the number of supplier in order to establish long-term relationship with a few suppliers who then play a critical role [8].

The relevant criteria for the selection of a supplier, which have been widely discussed in the literature, are presented in Table 1. These criteria form the basis for development a model of this research.

2.2. Conjunctive and disjunctive method

According to the cognitive processing level, MCDM techniques can be distinguished into two classes of: compensatory and noncompensatory [17]. The noncompensatory approach is cognitively less demanding than the compensatory approach since it requires the ordinal ranking of criteria based on the DM's priorities. The noncompensatory technique is the stepwise reduction of the set of alternatives without trading off their deficiencies along some evaluation criteria for their strengths along other criteria [9]. Conjunctive and disjunctive method are classified as noncompensatory, where

The conjunctive method: every criterion has a minimum cut-off value specified by the DM. Those alternatives that fail a cut-off value on any of the evaluation criteria are eliminated.

The disjunctive method: also uses cut-off values but in this method an alternative is eliminated if it fails to exceed a minimum cut-off value on at least one of the evaluation criteria.

2.3. Fuzzy analytical hierarchy process

Fuzzy set theory was oriented to the rationality of uncertainty due to imprecision or vagueness [26]. A tilde "~" will be placed above a symbol if the symbol represents a fuzzy set. A triangular fuzzy number (TFNs), is a popular format in research filed, is shown in Figure 1. In general, for triangular fuzzy number $\tilde{x}$ (m_1,m_2,m_3), which the parameters m_1,m_2,m_3 respectively denote the smallest possible value, the most promising value, and the largest possible value that describe a fuzzy event. The membership function $\mu(x)$ as follows

Table 1: Summary of the criteria for a material supplier selection from literature.

No.	Criteria	Explanation	References
1	Price (PR)	Regarding cost aspects of procuring from supplier.	[10], [13], [15], [19]
2	Quality (QLT)	The supplier may not only provide good products to the user but may also foster a long-term relationship with the user.	[13], [20], [25]
3	Compatibility (CPT)	It refers to the ability of the user and the supplier to work together in close coordination to achieve some common objectives.	[10], [20]
4	Service (SV)	Regarding service aspects from supplier.	[4], [13], [18]
5	Total cost (TTC)	It refers to the total cost of material, which should be minimum.	[10], [13]
6	Price stability (PST)	Price levels sufficiently stable so that expectations of change do not become major factors in cost decisions.	[13], [25]
7	Payment term (PMT)	Suitability of terms and conditions regarding payment of invoices, open accounts, sight drafts, credit letter and payment schedule.	[13], [16]
8	Appearance and functions (A&F)	It refers to the material can readily use in manufacturing process.	[13]
9	On time delivery (OTD)	Ability to meet delivery due dates.	[4], [13]
10	Flexibility in billing and payment (FBP)	Flexibility in billing and payment conditions increase goodwill between the user and the supplier.	[10], [16], [18], [19], [20]
11	Flexibility in operation and delivery (FOD)	Flexibility in operations and delivery may enable the user to give customized service to its customers, particularly in special requests.	[4], [10], [13], [15], [20]
12	Failure Prevention (FPV)	The materials/products are identified, handled, labeled, etc. in such a manner that a change or deterioration is prevented.	[15], [19], [20], [25]
13	Technical assistance and support (TAS)	It refers to the technical capability for supporting and assisting for customer about characteristic and property of material.	[13], [15], [16], [18], [19]
14	Cooperation and communication (C&C)	Communication capability maintained by each supplier.	[4], [13],

$$\mu(x)=\begin{cases} 1 & x=m_2 \\ \dfrac{x - m_1}{m_2-m_1} & m_1\le x\le m_2 \\ \dfrac{m_3-x}{m_3-m_2} & m_2\le x\le m_3 \\ 0 & \text{otherwise} \end{cases} \qquad (1)$$

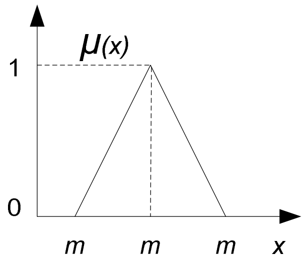

Figure 1: Membership function for triangular fuzzy numbers.

The analytic hierarchy process (AHP) is one of the extensively used MCDM [12]. One of the main advantages of this method is the relative ease with which it handles multiple criteria. Though the purpose of AHP is to capture the expert's knowledge, the conventional AHP still cannot reflect the human thinking style. Therefore, fuzzy AHP was developed to solve the hierarchical fuzzy problems.

2.4. Extent analysis method on fuzzy AHP

The extent analysis method on fuzzy AHP was presented by Chang, (1996). This method can describe as below

Let $X=\{x_1,x_2,...,x_n\}$ be an object set, and $U=\{u_1,u_2,...,u_m\}$ be a goal set. Therefore, m extent analysis values for each object can be obtained, with the following signs

$$M^1_{g_i}, M^2_{g_i},...,M^m_{g_i}, \qquad i=1,2,...,n. \qquad (2)$$

where all the are $M^j_{g_i}$ $(j=1,2,...,m)$ triangular fuzzy numbers. Then the value of fuzzy synthetic extent with respect to the i[th] object is defined as

$$S_i=\sum_{j=1}^{m} M^j_{g_i} \otimes \left[\sum_{i=1}^{n}\sum_{j=1}^{m} M^j_{g_i}\right]^{-1} \qquad (3)$$

The degree of possibility of $M_1 \ge M_2$ is defined as:

$$V(M_1\ge M_2)=\sup_{x\ge y}\left[\min\left(\mu_{M_1}(x),\mu_{M_2}(y)\right)\right] \qquad (4)$$

When a pair (x, y) exists such that $x\ge y$ and $\mu_{M_1}(x)=\mu_{M_2}(y)=1$, then we have $V(M_1\ge M_2)=1$. Since M_1 and M_2 are convex fuzzy numbers we have that

$$V(M_1\ge M_2)=1 \qquad \text{iff} \qquad m_1\ge m_2, \qquad (5)$$

$$V(M_2 \geq M_1) = \text{hgt}(M_1 \cap M_2) = \mu_{M_1}(d), \tag{6}$$

where d is the ordinate of the highest intersection point D between μ_{M_1} and μ_{M_2} (see Figure 2).

When $M_1 = (l_1, m_1, n_1)$ and $M_2 = (l_2, m_2, n_2)$, the ordinate of D is given by equation (7)

$$V(M_2 \geq M_1) = \text{hgt}(M_1 \cap M_2) = \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} \tag{7}$$

To compare M_1 and M_2, we need both the values of $V(M_1 \geq M_2)$ and $V(M_2 \geq M_1)$. The degree possibility for a convex fuzzy number to be greater than k convex fuzzy numbers $M_i (i = 1, 2, ..., k)$ can be defined by

$$\begin{aligned} V(M \geq M_1, M_2, ..., M_k) &= V[(M \geq M_1)\text{and}(M \geq M_2\text{and}...\text{and}(M \geq M_k)] \\ &= \min V(M \geq M_i) \qquad i = 1, 2, 3, ..., k. \end{aligned} \tag{8}$$

Assume that

$$d'(A_i) = \min V(S_i \geq S_k) \tag{9}$$

for $k = 1, 2, ..., n; k \neq i$. Then the weight vector is given by

$$W' = \left(d'(A_1), d'(A_2), ..., d'(A_n)\right)^T \tag{10}$$

where $A_i (i = 1, 2, ..., n)$ are n elements. Via normalization, the normalized weight vectors are

$$W = \left(d(A_1), d(A_2), ..., d(A_n)\right)^T \tag{11}$$

where W is a nonfuzzy number.

2.5. Analytic hierarchy process: A stochastic approach

In the AHP, the uncertainty is propagated through a hierarchy resulting in the uncertain values for the global AHP weights of decision alternatives. It was clear that, this uncertainty associated with subjective judgmental errors may affect the rank order of decision alternatives and consequently reduce the decision maker's confidence in the obtained results of the AHP [7]. From the study, the variance of the error parameter σ^2 can directly be estimated from the comparison matrix. A good estimate of the variance of error σ^2 is given by

$$\sigma^2 = \frac{2}{(n-1)(n-2)} \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} y_{ij}^2 \tag{12}$$

where n is the size of the matrix, a_{ij} represents the actual judgment ratio, $w_{ij} = w_i/w_j$ is the consistent judgment ratio formed from the priority vector $\boldsymbol{w} = (w_1, w_2, \ldots, w_n)$ computed from $\boldsymbol{A} = [a_{ij}]_{m\square n}$ and $y_{ij} = ln(a_{ij}/w_{ij})$.

Using approximate analysis and simulation, it was found that the variances of the local weights resulting from the subjective errors can be estimated in term of variance of error by

$$\sigma_{w_i}^2 = \frac{n^2 - 1}{n^2} \left[\sum_{i=1}^{n} w_i^2 - w_i^2 \right] \sigma^2 w_i^2 \tag{13}$$

where $\sigma_{w_i}^2$ presents the variance of the local weight estimates and provides a degree of accuracy.

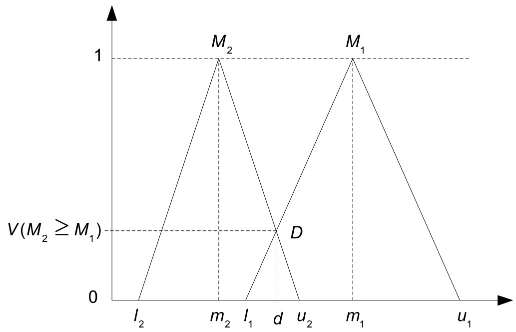

Figure 2: The intersection between M_1 and M_2.

3. Methodology

The proposed methodology allows for the selection of alternative suppliers in three steps: (i) the initial screening of the suppliers and (ii) an extent analysis method for the synthetic extent values of the pairwise comparisons and handling fuzzy AHP (iii) the fuzzy stochastic AHP approach for the final selection. Often, the initial screening of the providers is relatively easy but the final selection from the list of short-listed suppliers is a tough task. In this section, we present a schematic diagram of the proposed procedure as show in Figure 3. The various steps of this framework are described in brief as follows.

First of all, we find criteria which relate in the field of supplier selection, especially for material sourcing as exhibited in table 1. Second, the company identifies the potential suppliers who should be apprised of the business strategy of the company and its vision for future cooperation. Usually eight to ten providers may be considered for the initial appraisal. For the initial screening of the supplier we adopt the noncompensatory technique to directly screen from the criteria. Conjunctive and disjunctive methods are applied in this step. The extent analysis method on fuzzy AHP is performed to decide on the relative importance of each pair of factors in the same hierarchy. Finally, the fuzzy stochastic AHP is calculated the global weight variances accounting for judgmental errors resulting from inconsistent pairwise comparisons. Utilizing the global AHP weights and their corresponding estimated variances, Monte Carlo simulation is employed for handling the related uncertainty in the global AHP weights. This type of analysis provides more information for DM which makes more precise discriminations among competing alternatives [24].

4. Empirical Study

In order to maintain the confidentiality of the firm utilized in the case illustration, it is referred to as Company XYZ throughout the discussion. Company XYZ operates through two divisions, gold and gems. It is one of SMEs where states facility based in Lamphun. It purchases materials from suppliers and manufacturers them prior to delivering to the customer. These materials are provided from both local (Lamphun and Chiang Mai) and outside northern region suppliers. Therefore, the management at XYZ company decided to consider quality, compatibility, service, and price metrics etc. A total of criteria are selected as shown in Figure 4.

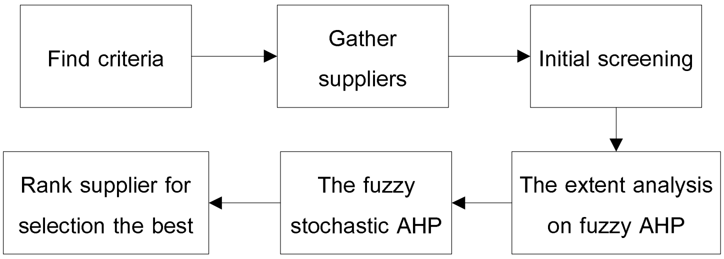

Figure 3: A schematic diagram of the proposed procedure.

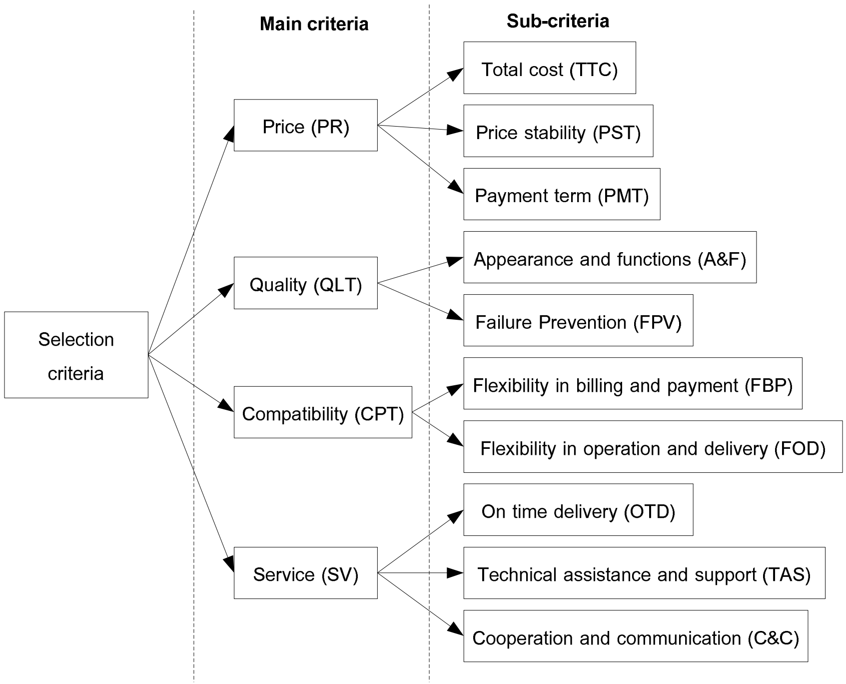

Figure 4: The selection criteria of the material supplier selection problem.

5. Results and Discussion

This paper uses linguistic importance weight and rating as show in Table 2. DM evaluated 8 suppliers in the first round by using conjunctive and disjunctive method. The qualified suppliers were rated greater than or equal to “Fair (F)” in all criteria. From initial screening, 3 candidate suppliers were used for the final selection. Table 3 exhibits linguistic evaluation data of them. Each criterion was judged by two DMs, the equal importance weights of individual DMs were assigned. Via pairwise comparison of main criteria in Table 4, extent analysis method on fuzzy AHP was adopted to calculate the weight vector. The following values are obtained by applying formula (3):

$S_{PR} = (2.52, 3.20, 4.00) \otimes (1/23.75, 1/18.48, 1/14.54) = (0.11, 0.17, 0.28)$,

$S_{QLT} = (2.35, 2.78, 3.75) \otimes (1/23.75, 1/18.48, 1/14.54) = (0.10, 0.15, 0.26)$,

$S_{CPT} = (4.75, 6.25, 7.75) \otimes (1/23.75, 1/18.48, 1/14.54) = (0.20, 0.34, 0.53)$,

$S_{SV} = (4.92, 6.25, 8.25) \otimes (1/23.75, 1/18.48, 1/14.54) = (0.21, 0.34, 0.57)$

Using formulas (5-7), $V(S_{PR} \geq S_{QLT}) = 1.0$, $V(S_{PR} \geq S_{CPT}) = 0.31$, $V(S_{PR} \geq S_{SV}) = 0.29$, $V(S_{QLT} \geq S_{PR}) = 0.87$, $V(S_{QLT} \geq S_{CPT}) = 0.24$, $V(S_{QLT} \geq S_{SV}) = 0.21$, $V(S_{CPT} \geq S_{PR}) = 1.0$, $V(S_{CPT} \geq S_{QLT}) = 1.0$, $V(S_{CPT} \geq S_{SV}) = 1.0$, $V(S_{SV} \geq S_{PR}) = 1.0$, $V(S_{SV} \geq S_{QLT}) = 1.0$, and $V(S_{SV} \geq S_{CPT}) = 1.0$ are obtained. Thus, the weight vector from Table 4 is calculated as $W = (0.12, 0.08, 0.40, 0.40)^T$. The DMs then compares the sub-criteria with respect to main criteria. The other tables will not be given in the paper because the calculation is similar.

Finally, adding the weights per candidate multiplied by the weights of the corresponding criteria, a final score is obtained for each candidate. Table 5 shows these scores.

Next, we calculate the variances of the relative local weights and consequently the variances of global weights from equation 12 and 13 which are displayed in Table 6 and Table 7, respectively. Using the simulation approach, the summary of output results of 1,000 replications is given in Table 8.

Table 2: TFNs of linguistic terms for the importance weights and ratings.

Importance weights of DM	Ratings of the suppliers	TFNs
Equally important (EI)	Very poor (VP)	(1/2, 1, 3/2)
Weakly more important (WMI)	Poor (P)	(1, 3/2, 2)
Strongly more important (SMI)	Fair (F)	(3/2, 2, 5/2)
Very strongly more important (VSMI)	Good (G)	(2, 5/2, 3)
Absolutely more important (AMI)	Very good (VG)	(5/2, 3, 7/2)

Table 3: Linguistic evaluation data related to candidate suppliers.

	TTC	PST	PMT	A&F	FPV	FBP	FOD	OTD	TAS	C&C
Company A	F	G	G	G	G	G	VG	F	G	G
Company B	G	G	F	VG	G	F	G	G	G	G
Company C	F	F	G	G	G	G	F	VG	F	VG

Table 4: The fuzzy evaluation matrix of the main criteria.

	PR	QLT	CPT	SV	W_C
Price	(1,1,1)	(1,3/2,2) (1/2,1,3/2)	(2/5,1/2,2/3) (2/5,1/2,2/3)	(2/5,1/2,2/3) (1/3,2/5,1/2)	0.12
Quality	(1/2,2/3,1) (2/3,1,2)	(1,1,1)	(1/3,2/5,1/2) (2/5,1/2,2/3)	(2/5,1/2,2/3) (2/5,1/2,2/3)	0.08
Compatibility	(3/2,2,5/2) (3/2,2,5/2)	(2,5/2,3) (3/2,2,5/2)	(1,1,1)	(1/2,1,3/2) (1/2,1,3/2)	0.40
Service	(3/2,2,5/2) (2,5/2,3)	(3/2,2,5/2) (3/2,2,5/2)	(2/3,1,2) (2/3,1,2)	(1,1,1)	0.40

Table 5: Final scores and sequence of suppliers.

Supplier	Final score	Sequencing
A	0.344	1
B	0.326	3
C	0.330	2

Table 6: The variances of the relative local weights.

Main criteria	$\sigma^2_{w_i}$
Price	3.51×10^{-3}
Quality	1.90×10^{-3}
Compatibility	2.28×10^{-2}
Service	2.28×10^{-2}

Table 7: The variances of global weights.

Supplier	σ^2
A	6.14×10^{-3}
B	5.36×10^{-3}
C	5.59×10^{-3}

Table 8: Summary of statistic and the simulation results for decision alternatives.

Supplier	Mean	S.D.	C.I.(95%)	Rank		
				1	2	3
A	0.344	0.0784	(0.1904, 0.4977)	39.2 %	32.4 %	28.4 %
B	0.326	0.0732	(0.1826, 0.4697)	31.7 %	34.2 %	34.1 %
C	0.330	0.0748	(0.1829, 0.4762)	29.1 %	33.4 %	37.5 %

6. Conclusions

Supplier A does not dominate with the confidence level of 95%. Thus, the null assumption that supplier A is probabilistic optimal is rejected. In this case, the stochastic analysis yields the preference ranking of supplier A, B and C respectively considering the degree of judgmental uncertainty found in the input data. The proposed stochastic approach is capable of calculating the variances of the global AHP weights as well as handling the uncertain behavior of them using Monte Carlo simulation.

Further research, the method of logarithmic least squares (for short LLMS) will be applied to compare the result of extent analysis method for consideration which method is proper to this problem.

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