Planning of Supplier Selection in Multisource Strategy Using Delphi, AHP, and TOPSIS

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Abstract

This study presents a supplier selection planning for companies that adopt multi source strategy, where some category of components supplied by several suppliers. Having several suppliers can be the right choice when a supplier has capacity problems, backup sources are needed to protect against material shortages, and the need to maintain competition among suppliers. Criteria for the supplier selection is quality, delivery, and cost activity performance of the suppliers. The Delphi method is used to obtain comparison of importance degree between all criteria. After that the data become input for criteria priority analysis using AHP method. Finally, the criteria priority data used as criteria weight for selecting supplier using TOPSIS method. The result of these three main steps in this study is supplier ranking that represents their performance of quality, delivery, and cost activity. Decision makers can use the supplier ranking data as reference for deciding future business intention with each supplier.

Keywords
Supplier selection, Multi source, Delphi, AHP and TOPSIS.

1. Introduction
To maintain business continuity companies must provide a variety of new products or services that meet market demands to satisfy customer needs. In order to realize these goals, companies need sufficient business profits to support their growth (Wang et al. 2013). Manufacturing companies are not making all components that required for manufacturing their finish goods by themselves. To obtain components they are purchasing it from one or some supplier. Companies that adopt multi source strategy likely have several suppliers to supply component to them. Having several suppliers can be the right choice when (Firouz, et al., 2017):
1. Supplier has capacity problems,
2. backup sources are needed to protect against material shortages, strikes, and disruptions from other suppliers,
3. The need to maintain competition among suppliers.

Company will have to assign the order to various suppliers in the multi-supplier scenario (or at least choose one among several providers), and then place the orders in accordance with the determined order allocation strategy (Wu, et al., 2023).
Supplier selection allows companies to assess, rank, and identify prospective suppliers (Islam, et al., 2022). Optimized supplier selection and order allocation processes can reduce costs and increase profit margins and production system efficiency (Muneeb et al. 2023).

1.1 Objectives
This research collects required data to assess supplier and then evaluate their performance to provide material considerations that can be used by decision makers to make decisions in selecting suppliers.

2. Literature Review
The process of choosing a supplier is understood to be a difficult multi-criteria decision-making (MCDM) problem that takes into account a number of potential suppliers and different evaluation criteria (X, et al., 2021). Because decision-making groups for supplier selection typically include several decision-makers from many professional departments, this task is getting more and more challenging for decision-makers. The proper decision should be made completely from many perspectives, including aggregating different decision makers' preferences, since different decision makers and stakeholders may have different preferences and objectives (Z., et al., 2019).

Combining two or more approaches to solve the same multiple criteria problem Hybrid MCDM (HMCDM) has become more popular in recent years as a decision-making tool. When HMCDM is used, a decision-maker or group of decision-makers can feel more confident in the outcomes. Due to its effectiveness in assisting decision-makers in handling a wide range of information, applications of HMCDM techniques for sustainability challenges have gained more attention (Zavadskas, et al., 2016).

Kermani et al. (2014) using quality, cost and delivery as criteria in their research about supplier selection refers to (Amid, et al., 2006) and (Talluri, 2003) (Kermani, et al., 2014). For sustainable supplier selection, quality of product is the highest ranked criterion based on the Fuzzy-AHP-MULTIMOORA computations and this is followed by product price (Orji & Ojadi, 2021).

2.1 Delphi

Delphi is a way for structuring group communication so that the process is efficient in allowing a group of people to deal with a difficult topic as a whole (Linstone & Turoff, 1975). The Delphi methodology, which determines agreement through repeated administration of anonymous questionnaires over the course of two or three rounds, is the most frequently reported consensus method. It is a systematic, isolated, indirect, multistage interaction method (McMilan, et al., 2016), (Waggoner, et al., 2016). The following are supplied to facilitate this "structured communication": some feedback on individual contributions of knowledge and information; some evaluation of the judgment or viewpoint held by the group; some opportunities for individuals to change their minds; as well as some anonymity degree for each response. Usually, Delphi must be used because the application has one or more of the following characteristics:

1. The problem is not matched by precise analytical techniques but makes use of collective subjective judgment
2. Individuals required to contribute to examining broad or complex issues do not have an adequate history of communication and may represent diverse backgrounds in terms of experience or expertise
3. It takes more individuals than can interact effectively in a face-to-face exchange
4. Time and cost make frequent group meetings impossible
5. The efficiency of face-to-face meetings can be increased by additional group communication processes
6. Disagreements between individuals are so severe or politically objectionable that the communication process requires referral and/or guarantee of anonymity
7. Heterogeneity of the participants must be maintained to ensure the validity of the results, i.e., avoid domination of personality quantity or strength (bandwagon effect)

2.2 Analytical Hierarchy Process

A general theory of measuring is the Analytic Hierarchy Process. In multilevel hierarchical systems, it is utilized to create ratio scales from both discrete and continuous paired comparisons. These comparisons may be based on precise measurements or on a fundamental scale that gauges the relative potency of preferences and emotions. The AHP has a special concern with departure from consistency and the measurement of this departure, and with dependence within and between the groups of elements of its structure (Saaty & Vargas, 2012). Its most widespread uses are in conflict resolution, resource allocation, and multi-criteria decision making (Saaty, 1980).

2.3 Technique for Order of Preference by Similarity to Ideal Solution

TOPSIS is based on concept that the optimal option should have the shortest distance from the positive ideal solution (PIS) and the farthest from the negative ideal solution (NIS). TOPSIS is quite easy to use and can provide a relative evaluation metric for the options. Depending on how this new alternative interacts with previous ones, there is a restriction on rank reversal when alternatives are added (García-Cascales & Lamata, 2012).
Main reasons of TOPSIS employment are as follows (Zeleny, 1982).

1. TOPSIS has a rational and understandable logic
2. Computational process of TOPSIS is straightforward
3. The idea allows for the pursuit of the best options for each criterion that is represented in a simple mathematical form
4. The importance weights are included in the comparison processes.

3. Methods

In general, this research divided into three steps. First is collecting comparison criteria using Delphi method, second is calculating criteria weight using AHP, and last is determining supplier ranking using TOPSIS. Framework of this research illustrated by figure below.

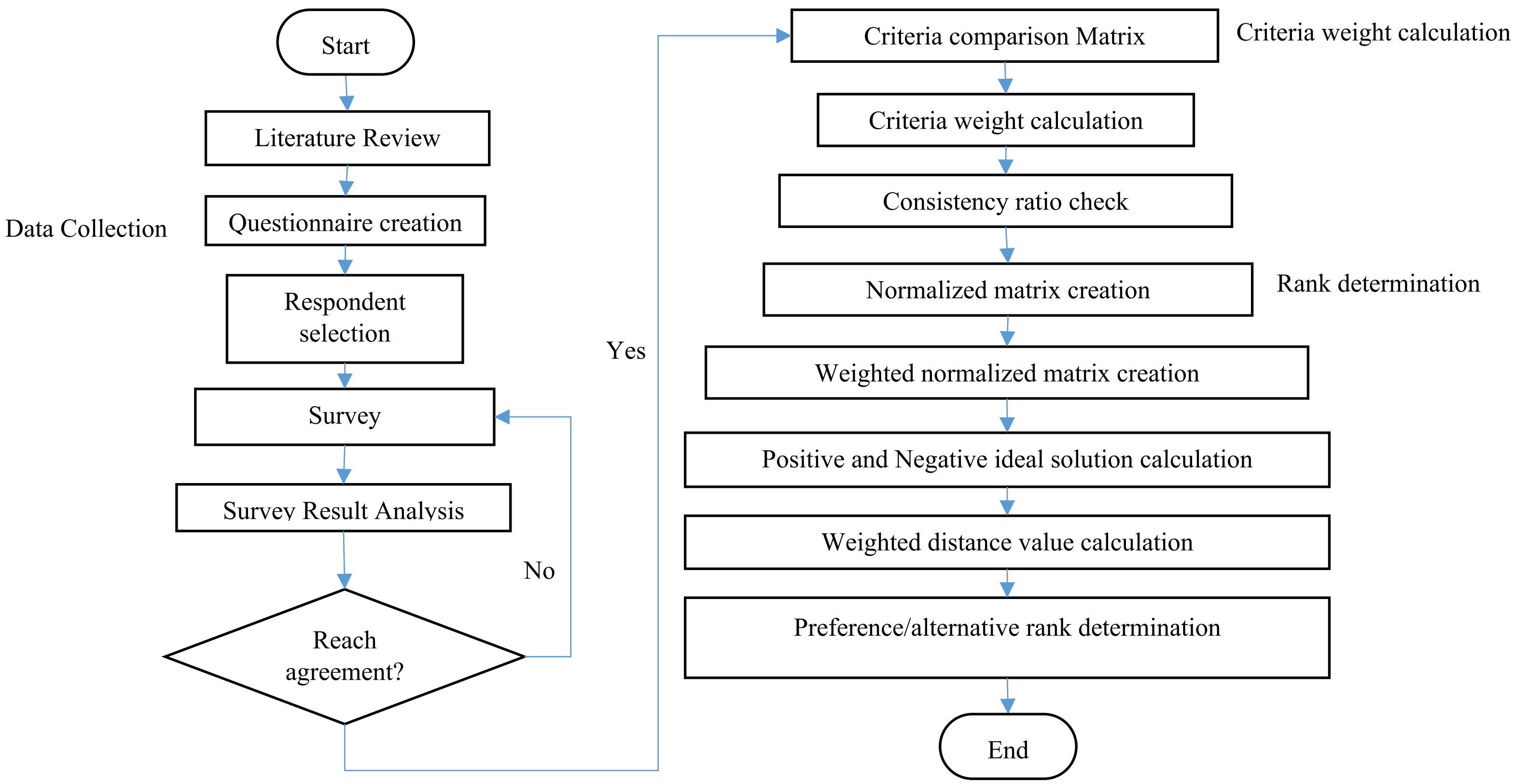

Figure 1. Research outline

3.1 Criteria Comparison

Delphi Method with support of survey and questionnaire tools will be used for collecting information about comparison of importance degree between criteria. The criteria are quality, delivery, and cost performance.

1. Criteria comparison

First round of Delphi conducted to obtain importance comparison between criteria.
In this round, experts asked to give their response about each question by giving score 1 to 5.
Question details are as follows.
Q1: quality more important than cost
Q2: quality more important than delivery
Q3: delivery more important than cost
Where 1 is strongly disagree and 5 is strongly agree.

Strongly disagree	1	2	3	4	5	Strongly agree

2. Importance degree of criteria

To find importance degree of each criteria, next rounds of Delphi are required.
In this round, experts asked to assess importance degree of a criteria compared to others through second questionnaire by giving score 1 to 9.
Q1: Quality compared to cost
Q2: Quality compared to delivery

Q3: Cost compared to delivery
Where 1 is equally important and 9 is extremely more important.
Equally important 1 2 3 4 5 6 7 8 9 Extremely more important

3.2 Weight Criteria Calculation

Comparison data that obtained in previous process will be used as input in weight criteria calculation. Then the next steps are:

1. Comparison of criteria/attributes

$$C = \begin{matrix} c_{11} & c_{12} & c_{13} & \cdots & c_{1n} \\ c_{21} & c_{22} & c_{23} & \cdots & c_{2n} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ c_{n1} & c_{n2} & c_{n3} & \cdots & c_{nn} \end{matrix}$$

C_{ij} is the importance comparison of i^{th} attribute to j^{th} attribute in relation to overall objective. Table 1 shows importance rate comparison guideline.

Table 1. Importance rate comparison

Importance rate	Meaning
1	Equally important
3	Moderately more important
5	Strongly more important
7	Very strongly more important
9	Extremely more important
2,4,6,8	Score Between two adjacent importance rate
Resiprocal	If element i has one of the numbers above compared to element j, then j has the opposite value when compared to i

2. Criteria weight calculation
Weighted normalized decision matrix is deployed to obtain criteria weight

$$W = [w_i]_{nx1}$$

Where $w_i = \sum_{j=1} \frac{m_{ij}}{n}$
i = 1,2,3…n, j = 1,2,3…n.
Consistency vector CV is required to show consistency value for different criteria

$$CV = [cv_i]_{1\ldots n}$$

Where $cv_i = \frac{Cw_i}{w_i}$ for i=1,2,…n.
Then determine the maximum Eigen value (λ_{max}).

$$\lambda_{max} = \frac{\sum_{i=1}^{n} cv_i}{n}$$

3. Consistency Ratio calculation
Consistency Index (CI)

$$CI = \frac{\lambda\, max - n}{n - 1}$$

λ max= total eigen value
n= number of elements

Determine *Random Index* (RI)
RI value refers to random consistency index matrix as shown on Table 2.

Table 2. Random index matrix

Matrix size	Random consistency index (RI)
1	0.00

2	0.00
3	0.58
4	0.90
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49

Consistency Ratio (CR) calculation

$$CR = \frac{CI}{RI}$$

where:
CI= Consistency Index
RI= Random Index.

3.3 Evaluate and determine rank.

In this process criteria weight that obtained by using AHP in previous process will be used as input. After that following these steps.

1. Alternative comparison and normalized matrix
   $r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i-1}^{m} x_{ij}^2}}$
2. Weighted normalized matrix
   $v_{ij} = r_{ij}$ x w_j
3. Positive and negative ideal solution
   y+ is: max y_{ij}, if j is benefit attribute
   min y_{ij}, if j is cost attribute
   y- is: min y_{ij}, if j is benefit attribute
   max y_{ij}, if j is cost attribute
4. Distance of alternatives from weighted positive and negative ideal solution
   $$D_i^+ = \sqrt{\sum_{j=1}^{n} (y_i^+ - y_{ij})^2 \quad ; \text{ i } = 1,2, \dots, \text{m}}$$
   $$D_i^- = \sqrt{\sum_{j=1}^{n} (y_{ij} - y_i^-)^2 \quad ; \text{ i } = 1,2, \dots, \text{m}}$$
5. Determination of relative closeness to Ideal solution
   $V_x \frac{(D_x-)}{(D_x-) + (D_x+)}$

6. Alternatives rank
   Rank orders determined based on relative closeness result. The bigger the value, the better the alternative vice versa.

4. Data Collection

Data collection process utilize the Delphi method with support of survey and questionnaire tools. Surveys are involving ten experts with three different expertise consist of quality, delivery, and cost. In this survey, experts asked to fill questionnaire refers to guidance on section 3.1. First round refers to section 3.1 point 1 guidance, meanwhile second and third round refers to point 2 (Table 3).

Table 3. Panel of experts

Experts	Expertise
1	Cost
2	Delivery
3	Delivery
4	Quality
5	Delivery
6	Quality
7	Quality
8	Cost
9	Cost
10	Quality

Goals of the first round of Delphi is obtain importance comparison between criteria. Recapitulation of Delphi round 1 shown on Table 4.

Table 4. Delphi round 1 recap

	Questions		
	Q1	Q2	Q3
Sum	37	42	22
Average	3.7	4.2	2.2
Result	Agree	Agree	Disagree

After importance comparison of criteria discovered in the first round, round 2 and 3 of Delphi are required to find importance degree of a criteria compared to another. Recapitulation of these two rounds shown on Table 5 and 6.

Table 5. Delphi round 2 recap

	Questions		
	Q1	Q2	Q3
Sum	37	56	39
Average	3.7	5.6	3.9

Table 6. Delphi round 3 recap

	Questions		
	Q1	Q2	Q3
Sum	33	58	36
Average	3.3	5.8	3.6
≈	3	6	4

5. Results and Discussion

5.1 Data collection results

Round 1 of Delphi usually using open ended question. if this research also does so, parameter that possibly affects supplier selection can be explored comprehensively. But in the other hand, reaching agreement of all experts or finding conclusion will take plenty of time. Due to that consideration instead of open-ended question utilization, literature review was conducted to acquire parameters of supplier selection.

Results of Delphi round 1 are:

1. Quality more important than cost
2. Quality more important than delivery
3. Cost more important than delivery.

Refers to Delphi round 2 recap table, Summary result of the second round as follows:

1. Quality moderately to strongly more important than cost
2. Quality very strongly more important than delivery
3. Cost moderately to strongly more important than delivery

Based on Delphi third round 3 recap shown on table below summary of round 3 is:

1. Quality moderately more important than cost
2. Quality strongly to very strongly more important than delivery
3. Cost moderately to strongly more important than delivery

Rater agreement is an important point in Delphi method that shows all experts are agree of the questionnaire result. Rater agreement test result can be seen in validation section. Delphi round 3 was conducted because in round 2 experts do not reach consensus. Round 3 is the last round of Delphi in this research. Result of this process will be used as AHP method input in the next process.

5.2 Numerical Results

Experts response of Delphi round 3 shown on Table 6 become input of criteria weight determination process and entered to criteria comparison matrix by following AHP rule as shown on Table 7.

Table 7. Criteria comparation matrix AHP

	Quality	Delivery	Cost
Quality	1	6	3
Delivery	0.17	1	0.25
Cost	0.33	4	1
Total	1.50	11.00	4.25

Criteria weight calculated by employing weighted normalized decision matrix (Table 8). Priority column shows the weight of each criteria, and Eigen value column will be used to calculate consistency ratio as verification process.

Table 8. Weighted normalized matrix AHP

	Quality	Delivery	Cost	Sum	Priority	Eigen value
Quality	0.666667	0.545455	0.705882	1.918004	0.64	0.96
Delivery	0.111111	0.090909	0.058824	0.260844	0.09	0.96
Cost	0.222222	0.363636	0.235294	0.821153	0.27	1.16
Total	1	1	1	3	1	3.08

Criteria weight from AHP process then used as input for supplier ranking determination by using TOPSIS method. The weight and criteria entered in criteria weight matrix, then classified as cost or benefit (Table 9).

Table 9. TOPSIS criteria weight matrix

	Quality	Delivery	Cost Activity
Weight	0.64	0.09	0.27
	Cost	Benefit	Benefit

To utilize the normalized matrix of TOPSIS, alternative performance should be arranged in a separated matrix as shown on Table 10-Table15.

Table 10. TOPSIS data input and divider

Alternative	Performance		
	Quality	Delivery	Cost Activity
Supplier 1	0.30	100.00%	0.99%
Supplier 2	0.60	99.99%	2.21%
Supplier 3	7.60	99.98%	1.21%

Divider	7.629547824	1.731877608	0.027070833

Further calculation starts from normalized matrix until alternative rank determination following TOPSIS rule as shown on section 3.3.

Table 11. TOPSIS normalized matrix (R)

	Quality	Delivery	Cost Activity
Supplier 1	0.03932081	0.577408	0.365707254
Supplier 2	0.07864162	0.57735	0.816376799
Supplier 3	0.99612719	0.577293	0.446975532

Table 12. TOPSIS Weighted normalized matrix

	Quality	Delivery	Cost Activity
Supplier 1	0.02513915	0.050204	0.1001005
Supplier 2	0.0502783	0.050199	0.223456672
Supplier 3	0.6368585	0.050194	0.122345056

Table 13. TOPSIS Positive and negative ideal solution

Positive	0.0251	0.0502	0.2235
Negative	0.6369	0.0502	0.1001

Table 14. TOPSIS Distance matrix

D1+	0.12335617	D1-	0.611719346
D2+	0.02513915	D2-	0.599410603
D3+	0.62001945	D3-	0.022244556

Table 15. TOPSIS preference (V) and alternative rank

Alternative	Preference	Rank
1	0.83	2
2	0.96	1
3	0.04	3

Refers to TOPSIS preference, alternative ranking order based on their performance is alternative 2, alternative 1, and alternative 3.

5.3 Graphical Results

Add graphical results here. Make sure to describe all figures and add inferences. If needed, add statistical analysis here.

5.4 Proposed Improvements

Use open-ended questionnaire to obtain comprehensive information about parameters for supplier selection from the experts, consider to use smaller α, and research about order allocation are required if company doesn't have strategy about it.

5.5 Validation

With α=10%, P-value of Delphi rater agreement test should be less than 0.1. The first round already meets this condition, meanwhile the second round is higher than 0.1 (Table 16-17). That is why experts given the opportunity to revise their response on the third round until rater agreement test results less than 0.1 which means experts reached a consensus.

Table 16. Delphi round 1 rater agreement

n	3
m	10
U	33.66667
S	216.6667
Maxs	746.8889
W	0.2901
r	0.211214
X^2	5.801845
df	2
P-value	0.054972

Table 17. Delphi round 2 rater agreement

n	3
m	10
U	44
S	218
Maxs	1732
W	0.1259
r	0.0287
X^2	2.5173
df	2
P-value	0.2840

In Table 18 we can see P-value of Delphi round 3 is less than 0.1 which means experts have reached consensus. So, criteria comparison data can be used to calculate criteria weight in the next process.

Table 18. Delphi round 3 rater agreement

n	3
m	10
U	42.33333
S	372.6667
Maxs	1544.222
Wx`	0.2413
r	0.157033
X^2	4.826594
df	2
P-value	0.08952

Consistency ratio assessment of criteria weight calculation explained in section 3.2 point 3. CR assessment result shown on Table 19 is less than 0.1. in brief, the criteria weight is consistent and can be used as input to evaluate alternatives performance and determine rank of them.

Table 19. Criteria weight CR assessments

CI	0.039364
RI	0.58
CR	0.067869

6. Conclusion

Supplier rank sequence based on performance evaluation is supplier 2, supplier 1, then supplier 3. Once the supplier rank determined, decision makers should allocate the orders following determined order allocation strategy or to the conditions that are most profitable to the company.

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