An analysis of supply chain collaboration index by using FAHP and SCCI: a case study of organic fertiliser company X, Indonesia

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Abstract. Supply chain collaboration is one of the most crucial variables of driving business success in organic fertiliser Companies, especially to maintain the continual flow from upstream to downstream. Therefore, understanding the level of collaboration factors is vital in sustaining the partnership as well as reducing any conflicts among stakeholders. This study aims to measure the depth of collaboration among Company X and its suppliers. The assessment of the supply chain collaboration index will perform Fuzzy Analytical Hierarchy Process (FAHP) to weight the collaboration behaviour factors and Supply Chain Collaboration Index (SCCI) to measure the depth level of collaboration. The collaboration behaviour factors examined in this study are including joint effort, collaboration values, sharing activities, adaptation, trust, power, stability, commitment, continuous improvement and coordination. Based on the computation process using SCCI, the collaboration index among company X and its supplier is 76.72 on a scale of 1-100. It implies that the collaboration is at a moderate level. Consequently, the company needs to recognise the low score factors and develop a strategy for improvement. Some aspects that deserve further attention are sharing activities, power, and stability. By enhancing the performance of these factors, the supply chain collaboration index can also be increased.

1. Introduction

Collaboration is one of the most significant aspects of supporting business activities in any industry. Collaboration refers to integration and coordination process among supply chain partners in developing business process and organisation in order to accomplish common goals [1]. Collaboration provides access to any information, knowledge, financial and non-financial supports needed in the supply chain process. Collaboration also increases the agility in supporting a sustainable supply chain and assists any stakeholders to work together in resolving the common problems and achieving the intended outcomes [2].

Collaboration behaviour is one of the functional requirements to build a solid partnership agreement. Collaboration behaviour refers to a set of organisational characteristics which are essential in managing the collaboration activities among stakeholders to achieve excellent collaboration quality [3, 4]. Collaboration quality should be managed and improved continuously to ensure fair and productive collaboration among stakeholders involved. There are ten collaboration behaviour factors that have been shown to be significant in reaching the common goals among stakeholders who join in collaboration activities. It consists of collaboration value, coordination, joint effort, sharing activities, adaptation,
trust, continuous improvement, commitment, stability, and power [3]. These collaboration behaviour elements will affect supply chain strategies to reach the market and improve supply chain performance.

Company X is an organic fertiliser company based in East Java, Indonesia, with a vision to provide the greatest service to the stakeholders through its business and product. To attain this goal, Company X needs to maintain collaboration among the stakeholders in the supply chain, including with the suppliers. Suppliers are company’s partner who provides Company X with the organic fertiliser product. Then, the organic fertiliser will be distributed under Company X’s brand to all regions in Indonesia. This type of partnership will optimise the distribution process in terms of amount, location, time as well as improve profitability for both parties [5].

Despite the profits and benefits earned from its collaboration activities, it is likely to occasionally generate ineffective and inefficient outcomes [6, 7]. Collaboration behaviour factors heavily influence supply chain collaboration activities. Hence, it is necessary to evaluate the collaboration behaviour factors that represent the supply chain collaboration activities. As a consequence, both parties will be able to identify which factors need to be developed to enhance the collaboration activities that can bring effective business activities. This study aims to assess the collaboration index among Company X and its suppliers by considering the collaboration behaviour factors.

Each factor in the collaboration behaviour has a varied importance level. Therefore, the importance level for each factor needs to be evaluated to achieve a highly accurate supply chain collaboration analysis. There are several approaches that can be utilised in determining the importance level, such as Rank Order Centroid (ROC), Simple Additive Weighting (SAW), Analytical Network Process (ANP) dan Analytical Hierarchy Process (AHP) [8-11]. However, this study will apply AHP since this approach can evaluate the qualitative factors from quantitative perspectives and yield a realistic result [12]. AHP is multicriteria decision-making that can simplify the assessment problem and avoid the randomness of weighting factors [8, 13].

Moreover, AHP weights the independent factors systematically by breaking down the problem into smaller and superficial paired comparison judgments [14]. However, since it involves human judgement to evaluate the collaboration activities level, this assessment has relatively high ambiguity. Therefore, fuzzy logic is applied to the AHP process to minimise vagueness in the assessment process and increase accuracy [15].

After evaluating the importance level of each factor, the collaboration quality level can be assessed. There are several methods that can be applied in evaluating the collaboration quality level, such as Graph Theory, Structural Equation Modelling (SEM) dan Supply Chain Collaboration Index (SCCI)[16-18]. SCCI will be used in this study since this method can illustrate the collaboration level from various indicators explicitly from all stakeholders’ perspectives [17]. Besides, it can measure the index of collaborative practice from a collaboration behaviour factors perspective. The integration of FAHP and SCCI can provide a comprehensive result of the supply chain collaboration index by considering the importance level of each behaviour factor. In addition, based on the index level, the strategy to improve the collaboration performance will be suggested.

2. Material and methods

2.1. Data collection

The data collection was initiated by designing the questionnaires to gather all information relevant to the research objective. There are two questionnaires in a closed-ended format had been used in this study. The first questionnaire is a pairwise comparison to assess the weight of criteria, representing the important priorities of the collaboration behaviour factors. Three experts as respondents were asked to rate the relative importance of two criteria by using a 1-9 scale that indicated equally important (1), weakly more important (3), strongly more important (5), very strongly more important (7), and extremely more important (9). The second questionnaire assesses the degree of supply chain collaboration activities, representing the collaboration index. In this study, ten factors influencing collaboration behaviour are examined. These factors represent the significant factors in fostering and
maintaining collaboration among stakeholders in the supply chain [3]. The detail of the factors can be seen in Table 1. The Five-point Likert Scale was used here, then converted into eleven scales for index calculation. According to Kumar and Banerjee [19], the scale range in SCCI should be N+1, which is N is the total factor. This questionnaire was then distributed to 30 suppliers of organic fertiliser in Company X.

### Table 1. Collaboration behaviour factors in supply chain.

| Factors               | Definition                                                                                                                                 |
|-----------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| Joint Effort          | Collaborative activities among the supply chain members in the decision-making process regarding planning, executing, and assessment at the operational, tactical, and strategic levels. |
| Sharing activities    | The willingness to share asset, profit, and risk among supply chain members.                                                                  |
| Collaboration Value   | The fundamental characteristics of the organisation in strengthening the supply chain collaboration value to build harmony among stakeholders.       |
| Adaptation            | The company’s ability in aligning the goal, strategy, resources, and supply chain process with its partners.                                   |
| Trust                 | The willingness to trust and rely on other parties in achieving mutual goals.                                                                |
| Commitment            | The willingness of the organisation to maintain and improve its relationship over time.                                                        |
| Power                 | The ability of the company to positively influence the other parties’ action and decision.                                                    |
| Continuous Improvement| The ability of the company to continually improve its performance.                                                                           |
| Coordination          | The interaction among stakeholders to align their perspectives and goals by cooperating effectively.                                           |
| Stability             | The awareness of the stakeholders to act cooperatively in achieving the common objective.                                                    |

Source: [3, 16, 20-23]

### 2.2. Integrated model Fuzzy Analytic Hierarchy Process (FAHP) – Supply Chain Collaboration Index (SCCI)

Data were analysed in two stages. Firstly, the importance level of collaboration behaviour factors was examined by using FAHP. Before processing the data to the next step, the consistency ratio (CR) for each question in pairwise comparison had to be assessed. This step was conducted to ensure that all answers were consistent and valid with the value of CR ≤ 0.1 [24]. The equation to calculate CR can be seen below.

\[
CI = \frac{(\lambda_{max} - n)}{(n - 1)} \tag{1}
\]

\[
CR = \frac{CI}{RI} \tag{2}
\]

where CI is the consistency index, \(\lambda_{max}\) is the largest eigenvalue, n is the number of factors being compared, and RI is a random index developed by [25] which can be seen in Table 2.

| Matrix order (n) | 3    | 4    | 5    | 6    | 7    | 8    | 9    | 10   |
|------------------|------|------|------|------|------|------|------|------|
| RI               | 0.58 | 0.90 | 1.12 | 1.24 | 1.32 | 1.41 | 1.45 | 1.49 |
b. Calculate the geometric mean of fuzzy comparison values of each criterion by using equation (4).

\[ \tilde{r}_i = \left( \prod_{j=1}^{n} d_{ij} \right)^{1/n}, \quad i = 1, 2, \ldots, n \]  

(4)

c. Calculate the fuzzy weight of each criterion by following these steps:
1) Determine the vector summation of each \( \tilde{r}_i \)
2) Find the inverse of the summation vector and replace the fuzzy triangular number.
3) Multiply each \( \tilde{r}_i \) with reverse vector to find the fuzzy weight of criterion I (\( \tilde{w}_i \))

\[ \tilde{w}_i = \tilde{r}_i \otimes (\tilde{r}_1 \oplus \tilde{r}_2 \oplus \ldots \oplus \tilde{r}_n)^{-1} \]
\[ = (l \tilde{w}_i, m \tilde{w}_i, u \tilde{w}_i) \]  

(5)
d. Since \( \tilde{w}_i \) are fuzzy triangular number, defuzzification should be carried out by using the centre of area method:

\[ M_i = \frac{3}{l \tilde{w}_i + m \tilde{w}_i + u \tilde{w}_i} \]  

(6)
e. \( M_i \) is a non-fuzzy number, and the normalisation process is implemented by using equation (6):

\[ N_i = \frac{M_i}{\sum_{i=1}^{n} M_i} \]  

(7)

Once the weight of each factor determined, the next step is assessing the collaboration index with Kumar and Banerjee [19] model below:

\[ SCCI = \frac{\sum_{i=1}^{n} \frac{w_i}{x_i} - \sum_{i=1}^{n} w_i}{n \sum_{i=1}^{n} w_i} \times 100 \]  

(8)

Where:
- \( w_i \): the weight of collaboration behaviour factor \( i \)
- \( x_i \): the average of value measurement of collaboration behaviour factor \( i \)
- \( n \): the number of collaboration behaviour factors

3. Results and discussion

3.1. The importance level of collaboration behaviour factors
The pairwise comparison was created based on the experts’ response to the questionnaires. Before performing further analysis, the consistency of the respondents’ result was evaluated to ensure the accuracy of the weighting process. The data obtained has a consistency ratio of 0.097. According to Saaty [25], the assignment of judgement can be categorised as consistent and acceptable if the CR < 0.1. The pairwise comparison is created once the data has been checked for consistency. After that, the result of the pairwise comparison was converted into a Triangular Fuzzy Number (TFN). Meanwhile, the weight of each criterion was calculated by using Geometric Mean to determine the importance level. The importance level of each collaboration behaviour factor is presented in Table 3.

As seen in Table 3, the most significant factor among stakeholders in organic fertiliser is sharing activities. Company X shares the facility, risk, raw material, technology, and incentive with the suppliers, while suppliers share the organic fertiliser as the primary commodity in this business process. Anbanandam, Banwet and Shankar [16] stated that sharing activities in the partnership process can be beneficial in supply chain risk mitigation and increase the competitive advantages. On the other hand, coordination has the lowest priority compared to other factors. It is because Company X and its suppliers have managed a clear and well-structured collaboration system. Therefore, without performing regular coordination, the collaboration of both parties is still well-organised. However, a centralised coordination mechanism will allow sharing activities and reduce the supply chain costs to create a more transparent and effective operation process. [27, 28].
Table 3. The importance level of collaboration behaviour factor.

| Collaboration behaviour Factor | Weight | Priority |
|-------------------------------|--------|----------|
| Joint Effort (X₁)             | 0.1003 | 5        |
| Sharing activities (X₂)       | 0.1475 | 1        |
| Adaptation (X₃)               | 0.1064 | 4        |
| Collaboration value (X₄)      | 0.0865 | 8        |
| Trust (X₅)                    | 0.0866 | 7        |
| Coordination (X₆)             | 0.0587 | 10       |
| Commitment (X₇)               | 0.0752 | 9        |
| Power (X₈)                    | 0.1431 | 2        |
| Continuous Improvement (X₉)   | 0.0881 | 6        |
| Stability (X₁₀)               | 0.1075 | 3        |

3.2. Supply chain collaboration index

After the importance level of each factor has been determined, the supply chain collaboration index can be calculated as shown in Table 4 below.

Table 4. Supply chain collaboration index.

| Factor                     | Weight | Collaboration score | Index  | Rank |
|----------------------------|--------|---------------------|--------|------|
| Joint Effort (X₁)          | 0.1003 | 9.152               | 0.918  | 5    |
| Sharing activities (X₂)    | 0.1475 | 7.392               | 1.090  | 2    |
| Adaptation (X₃)            | 0.1064 | 9.174               | 0.976  | 3    |
| Collaboration value (X₄)   | 0.0865 | 9.196               | 0.795  | 8    |
| Trust (X₅)                 | 0.0866 | 9.548               | 0.827  | 6    |
| Coordination (X₆)          | 0.0587 | 8.272               | 0.486  | 10   |
| Commitment (X₇)            | 0.0752 | 9.152               | 0.688  | 9    |
| Power (X₈)                 | 0.1431 | 8.14                | 1.165  | 1    |
| Continuous Improvement (X₉)| 0.0881 | 9.108               | 0.802  | 7    |
| Stability (X₁₀)            | 0.1075 | 8.602               | 0.925  | 4    |

$$\sum = 1.0000 \quad 87.736 \quad 8.672$$

$$SCCI = \frac{\sum_{i=1}^{n}w_i x_i - \sum_{i=1}^{n}w_i x}{n^2 \sum_{i=1}^{n}w_i} \times 100 = \frac{8.672 - 1.000}{10 \times 1.000} \times 100 = 76.72$$

Table 4 demonstrates that the highest collaboration behaviour factor in practice is trust. It is known that Company X and its supplier have built a strong mutual trust in their partnership. Company X strongly believes that its suppliers will provide a product with exceptional grade. On the other hand, the suppliers also have high confidence that Company X will offer high profitability in this business process. A partnership with a high degree of trust has a better possibility of generating new business opportunities [29].

Moreover, collaboration value, adaptation, joint effort, commitment, and continuous improvement have a score greater than 9. It means that the stakeholders share collaboration values such as mutual understanding and interpersonal relationship [3]. They also commit to adjusting their strategies to fit each other and keep a better performance in the long-term partnership process. In addition, they work together in arranging several activities to fulfil market demand at the operational and tactical level. This activity will result in better demand management and ease both parties to solve the limited resources problem [30].
However, several factors with high importance level show lower collaboration activities score (sharing activities, power, stability). Therefore, after calculating the total collaboration index (Equation 9) among Company X and its suppliers, it is categorised as moderate level (76.72). Sharing activities is a critical factor to consider when it comes to collaborative activities. Both Company X and its suppliers should balance the sharing risk, losses, and benefit during the process due to product delivery delays or inferior product quality. Risk sharing in supply chain activities will increase stakeholder involvement and encourage them to contribute more [3, 31]. Additionally, they should commit to aligning their strategy and resources to achieve a specific mission: providing a high-quality product and excellent customer service through sharing material, information, and technology.

Furthermore, power is also critical in collaboration activities since it can drive the partnership and its elements to attain the common goals. Company X has the power to organising the suppliers, managing the resources, and supervising supply chain activities. However, Company X should optimise the resources management and assure a seamless supply chain process in practice. Stakeholders with the dominant resources will continue to maintain, facilitate, and support their partners to build effective collaboration [32].

Stability is also one of the factors that should be given more attention. Suppliers should be able to adjust and develop their production capabilities to meet the customer demand based on the forecasting result of Company X. On the other hand, Company X should be more flexible to various enterprises with diverse capabilities and characteristics. Hence, maintaining stability may improve trust and lead to a long-term partnership to gain more significant benefits [33, 34].

4. Conclusions
Collaboration behaviour is one of the functional requirements to establish a solid partnership agreement in supply chain activities among Company X and its suppliers. However, each factor in the collaboration behaviour has a different importance level. According to the research, the most important to the least important factors in the collaboration behaviour are sharing activities ($X_2$), power ($X_8$), stability ($X_{10}$), adaptation ($X_3$), joint effort ($X_1$), continuous improvement ($X_9$), trust ($X_5$), collaboration value ($X_4$), commitment ($X_7$), and coordination ($X_6$). Furthermore, these factors affect the supply chain collaboration index. Based on the computation using SCCI, the collaboration index among company X and its supplier is 76.72 on a scale of 1-100. It shows that the collaboration is classified as moderate level. Thus, the company must review the low-scoring factors and devise an improvement plan. The factors that demand more attention are sharing activities, power, and stability. The performance of these factors can be managed by aligning their strategy and resources to reach the common goal, strengthening power in directing the partnership and its elements, and adjusting as well as developing their capabilities to gain a long-term partnership.

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