# Inter-departmental collaborative evaluation model based on the performance indicators

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**Abstract:** Based on the inter-departmental collaborative demand evaluation, this paper constructs a collaborative evaluation model between departments based on the application of synergy theory in supply chain management. This model involves five business segments: requirements planning, bidding procurement, contract management, performance delivery, operation and maintenance, and their corresponding 14 secondary indicators. The fuzzy set theory is used to calculate the target weight and finally the sample synergy evaluation result is obtained. Taking the bidding procurement process of the State Grid Corporation of China as an example, the conclusion is drawn through the application of the model. This model can effectively reflect the characteristics of inter-departmental collaboration, identify synergetic weaknesses, and provide new ideas for the design of future departmental performance indicators.

## 1. Introduction

The theory of synergetic was first proposed by the German physicist Hermann Haken in 1971 and gradually developed into a new discipline. In recent years, synergetic theory has been widely used in the field of supply chain management. In 1994, Anderson and Lee proposed that the development trend of the new generation supply chain is the collaborative supply chain [1]. Since then, supply chain collaboration has become a hot topic in the field of supply chain management. Supply chain collaboration refers to the coordination and mutual efforts of each node in the supply chain to improve the overall competitiveness of the supply chain, and to develop toward a common goal [2]. Supply chain collaboration can be divided into internal collaboration and external collaboration according to different members. At present, supply chain collaboration research mainly focuses on external collaborative research.

External collaboration that refers to the mutual synergy between the upstream and downstream members of the supply chain mainly studies how to improve the overall competitiveness of the supply chain, especially to improve the overall efficiency through the distribution of benefits among various enterprises [3,4] and information sharing [5, 6]. Internal collaboration refers to the collaboration and coupling of different departments of the enterprise and let them collaborate to complete the mission [7]. Compared to external collaboration, internal coordination does not involve issues such as profit distribution because the departments belong to the same enterprise. Therefore, internal collaboration is mainly to establish high-quality information transmission and information sharing, which is necessary to achieve synergy [8]. Business processes involve multiple departments, and each business segment involving multiple departments generates a synergetic demand. With each department as the node and the inter-departmental collaboration demand as the connection, a collaborative demand network can be formed, and the network theory can be used to analyze the collaborative demand [9, 10].

Different from the traditional supply chain collaborative research to improve the overall interests of the supply chain, in the new situation of electric power reform, ensuring the timely supply of engineering construction materials has become the focus of power system construction. For the bidding procurement business process, it means to shorten the procurement time as much as possible to ensure the supply of materials and make it the ultimate goal of inter-departmental coordination.

This paper, which starts from the inter-departmental collaborative demand evaluation, combines the bidding procurement business process to analysis the coordination demand and demand satisfaction between various departments. We analyse the impact of the synergistic demand between different departments on the total bidding procurement time by constructing a timeliness function.

## 2. Another section of your paper Model of synergy degree evaluation index system

In the entire material supply chain coordination system, different departments or units are related to each other in each business link. The coordination efficiency among the various entities directly affects the smoothness of the business links. The performance of each business segment will in turn reflect the degree of coordination between the supply chain entities. According to the design idea of the synergy degree index system and taking into account the operability of the indicators in actual use, the performance index that reflects the degree of synergy between departments is selected to construct the evaluation index system.

In the process of constructing the indicator system, we first analyze the synergistic needs of different departments involved in each link, and then evaluate the collaboration between departments and professions from the perspectives of time, demand and efficiency.

The first is the time dimension. According to the project management theory, in order to ensure that the project and business process are completed in time, the relevant work of each department in the process and the inter-departmental collaborative work should be completed within the specified time. Therefore, whether the departments can complete their own business work within a specified time is a manifestation of the synergetic degree between departments.

The second is the demand dimension. The collaborative work between departments is mainly based on the exchange of relevant information and materials. Therefore, whether they can provide relevant materials required by other departments according to regulations is a manifestation of the synergetic degree among departments. Since it is difficult to obtain the degree of demand satisfaction in the actual operation process, and each department in the relevant business process has its own division of labor, it is considered to evaluate the demand satisfaction by using relevant indicators of the business completion situation.

The third is the efficiency dimension. In the business processes involving multiple departments and professions, the professional completion of each department will also affect other departments. The completion of the pre-order department will significantly affect the relevant work efficiency of the follow-up departments, so the efficiency collaboration is also a manifestation of synergy.

We took the State Grid Corporation of China's bidding procurement related business process as an example. The collaborative quality and efficiency evaluation indicator system is constructed by considering the life cycle thinking of materials. From the generation of demand to the final material scrapping, it involves a series of business processes such as requirements planning, bidding procurement, contract management, performance delivery, operation and maintenance, etc., and each link involves different professional departments. Through collaborative demand analysis, combined with the characteristics of business links, and with reference to the opinions of experts, the five links are refined to 14 indicators. Under corresponding link, each indicator can measure the satisfaction degree of each collaborative demand. The specific indicator system is as follows (Table 1):

Table 1. Synergy degree evaluation index system

| Link | Index | Attributes | Calculation method |
|---|---|---|---|
| Requirements Planning | Centralized procurement rate | + | Centralized procurement rate = Total centralized purchase amount / Purchase amount×100% |
| | Accuracy rate of planed declaration | + | Accuracy rate of planed declaration =(1- Purchase plan error entries /Total entries)×100% |
| | Standardization rate | + | Standardization rate = Standardized item entries /Total item entries×100% |
| Bidding procurement | Prequalification completion rate | + | Prequalification completion rate = Actual completion of prequalification entries / Planned completion of prequalification entries×100% |
| | Qualification ability verification completion rate | + | Qualification ability verification completion rate = Actual completion of qualification verification entries / Planned completion of qualification verification number of entries×100% |
| | Bidding procurement success rate | + | Bidding procurement success rate =(1- Number of abortive packages / Number of total packages)×100% |
| Contract management | Contract signing on-time rate | + | Contract signing on-time rate = The amount of the contract that corresponds to the successful bid result within 30 days/ Total amount of winning results×100% |
| | Contract settlement completion rate | + | Contract settlement completion rate= Material contract to loan payment completion amount / Material contract to loan payment payable amount×100% |
| Performance delivery | On-time delivery rate | + | On-time delivery rate = Entries of items delivered on time /Entries of items that should be delivered according to plan×100% |
| | Sampling plan completion rate | + | Sampling plan completion rate = Entries of actual execution items in the sampling plan / Total entries of items in the sampling plan×100% |
| | Average inspection time | - | Average inspection time = Total inspection time / Total number of batches inspected |
| Operation and maintenance | Average malfunction response time | - | Average malfunction response time = Total malfunction response time /Total number of malfunction |
| | Operation and maintenance plan completion rate | + | Operation and maintenance plan completion rate = Actual execution entries in the operation and maintenance plan / Total entries in the operation and maintenance plan×100% |
| | Information record integrity rate | + | Information record integrity rate = Information record entries / Required information record entries×100% |

## 3. Synergy degree evaluation method

After completing the establishment of the synergy indicator system, In order to effectively solve the problem of subjective, qualitative and fuzzy input language and information in the process of weight distribution, the fuzzy set theory is combined with the comprehensive evaluation method, and the weight of each index system is determined by the triangular fuzzy number method. After the weight of the indicator system is determined Calculate the synergy score for each sample. The specific analysis steps and methods are as follows:

Step 1: Using the fuzzy set theory to quantitatively describe the subjective qualitative language evaluation terminology.

In general, the triangular fuzzy number $R$ is expressed as $\left(r_l, r_m, r_u\right)$, and its characteristic function (membership function) can be expressed as the following equation, where $r_u \geq r_m \geq r_l > 0$, $r_l$ and $r_u$ denote the lower and upper bounds of $R$, respectively. $r_m$ Denotes the median value of $R$ membership.

$$\mu_R\left(\chi\right) = \begin{cases} \left(\chi - r_l\right) / \left(r_m - r_l\right), & \chi \in \left[r_l, r_m\right] \\ \left(r_u - \chi\right) / \left(r_u - r_m\right), & \chi \in \left[r_m, r_u\right] \\ 0, \chi \in \left(-\infty, r_l\right] \bigcup \left[r_u, +\infty\right) & \end{cases} \tag{1}$$

Step 2: Determine the weight set W of the indicators at all levels of the indicator system.

For each level of indicators, the above-mentioned indicators attached to them are compared. The triangular fuzzy number complementary judgment matrix is established $\tilde{R} = \left(\tilde{r}_{ij}\right)_{n \times n}$. Set $\tilde{r}_{ij} = (r_{lij}, r_{mij}, r_{uij})$, $\tilde{r}_{ji} = (r_{lji}, r_{mji}, r_{uji})$, where $r_{lij} + r_{uji} = r_{mij} + r_{mji} = r_{uij} + r_{lji} = 1$, $r_{lii} = r_{mii} = r_{uii} = 0.5$, $0 \leq r_{lij} \leq r_{mij} \leq r_{uij}$, $i, j \in N$. Thus, we can determine the weight of respective indicators. $\tilde{r}_{ij}$ Denotes the importance scale of the index $x_i$ and the index $x_j$ relative to the upper level indicator to which it is attached. After that, according to the formula, the expected value of the triangular fuzzy number can be obtained. In this paper, $\lambda = 0.5$.

$$E\left(R\right) = \left(\left(1-\lambda\right) r_l + r_m + \lambda r_u\right)/2 \tag{2}$$

$$E\left(C\right) = \left(c_l + 2c_m + c_u\right) / 4 \tag{3}$$

Triangular fuzzy number complementary judgment matrix is to determine the weight of each type of indicators. During the establishment process, the consistency of the information before and after of the same founder and the degree of preference consistency of the different founders should be within a certain allowable range. Therefore, the judgment matrix should be tested for consistency.

$$CR = CI / RI \tag{4}$$

$$CI = \frac{1}{n(n-1)} \sum_{1 \leq i < j \leq n} \left[ \frac{E\left(\tilde{r}_{ij}\right)}{E\left(\tilde{r}_{ji}\right)} \times \frac{r_j}{r_i} + \frac{E\left(\tilde{r}_{ji}\right)}{E\left(\tilde{r}_{ij}\right)} \times \frac{r_i}{r_j} - 2 \right] \tag{5}$$

Among them, $CI$ is the consistency judgment index, $r_i$ is the weight of the evaluation index $x_i$. $RI$ Is the average random consistency indicator, which is used to correct the $CI$. Calculate $CR$. If $CR < 1$, it means that the triangular fuzzy number complementary judgement matrix has good consistency. Otherwise, it must be consistently modified or reconstructed until the triangular fuzzy number complementary judgment matrix passes the consistency test.

After passing the consistency test, starting from the bottom layer, the weights corresponding to each type of indicators are calculated in turn. $R=\left\{r_1,\cdots,r_i,\cdots,r_m\right\}$ , $\sum_i^m r_i=1$ ; $R_i=\left\{r_{i1},\cdots,r_{ij},\cdots,r_{in}\right\}$, $\sum_j^n r_{ij}=1$ etc.

$$r_i=\frac{\sum_{j=1}^n \tilde{r}_{ij}}{\sum_{i=1}^n\sum_{j=1}^n \tilde{r}_{ij}}=\frac{\sum_{j=1}^n\left(r_{lij},r_{mij},r_{uij}\right)}{\sum_{i=1}^n\sum_{j=1}^n\left(r_{lij},r_{mij},r_{uij}\right)}$$
$$=\frac{\left(\sum_{j=1}^n r_{lij},\sum_{j=1}^n r_{mij},\sum_{j=1}^n r_{uij}\right)}{\left(\sum_{i=1}^n\sum_{j=1}^n r_{lij},\sum_{i=1}^n\sum_{j=1}^n r_{mij},\sum_{i=1}^n\sum_{j=1}^n r_{uij}\right)} \tag{6}$$
$$=\left(\frac{\sum_{j=1}^n r_{lij}}{\sum_{i=1}^n\sum_{j=1}^n r_{uij}},\frac{\sum_{j=1}^n r_{mij}}{\sum_{i=1}^n\sum_{j=1}^n r_{mij}},\frac{\sum_{j=1}^n r_{uij}}{\sum_{i=1}^n\sum_{j=1}^n r_{lij}}\right)$$

Step 3: Sample determination and standardization of indicators.

Select n samples, m indicators, then $x_{ij}$ is the value of the j indicator of the $i$ sample. Since the units of measurement of the various indicators are not uniform, before they can be used to calculate the comprehensive indicators, we must first standardize them to solve the homogenization of the different kind indicators. Moreover, since the positive indicator and the negative indicator value represent different meanings (the higher the positive indicator value, the better; the lower the negative indicator value, the better). Therefore, for high and low indicators, we use different algorithms for data standardization:

Positive indicator:

$$x_{ij}^{'}=\left[\frac{x_{ij}-\min(x_{1j},x_{2j},...,x_{nj})}{\max(x_{1j},x_{2j},...,x_{nj})-\min(x_{1j},x_{2j},...,x_{nj})}\right]\times 100 \tag{7}$$

negative indicater:

$$x_{ij}^{'}=\left[\frac{\max(x_{1j},x_{2j},...,x_{nj})-x_{ij}}{\max(x_{1j},x_{2j},...,x_{nj})-\min(x_{1j},x_{2j},...,x_{nj})}\right]\times 100 \tag{8}$$

$x_{ij}^{'}$ Is the value of the j indicator of the $i$ sample. For convenience, we still record $x_{ij}^{'}=x_{ij}$ .

Step 4: Calculate the evaluation value of each indicator

According to the scores of each sample on the 14 secondary indicators, combined with the weight of the indicator system, the weighted total score is calculated, which is the result of the evaluation of the synergy of each sample.

## 4. Illustration analysis

Taking the bidding procurement process of the State Grid Corporation of China as an example, relevant experts within the company are invited to allocate the weight of the indicator system, and the company's business data is used to calculate the company's synergy evaluation value.

First, four experts establish a triangular fuzzy number complementary judgment matrix (Table 2) for the first-level indicator. Then, calculate the first-level indicator weight value (Table 3).

Table 2. Triangular fuzzy number complementary judgment matrix of first-level indicator

| Triangular fuzzy number complementary judgment matrix | | Evaluation index | | | | | Consistency ratio(CR) |
|---|---|---|---|---|---|---|---|
| | | Requirements Planning | Bidding procurement | Contract management | Performance delivery | Operation and maintenance | |
| P1 | Requirements Planning | (0.5,0.5,0.5) | | | | | 0.01798 |
| | Bidding procurement | (0.55,0.5,0.45) | (0.5,0.5,0.5) | | | | |
| | Contract management | (0.3,0.5,0.7) | (0.3,0.5,0.7) | (0.5,0.5,0.5) | | | |
| | Performance delivery | (0.65,0.55,0.45) | (0.55,0.5,0.45) | (0.7,0.6,0.5) | (0.5,0.5,0.5) | | |
| | Operation and maintenance | (0.55,0.5,0.45) | (0.4,0.4,0.5) | (0.65,0.65,0.6) | (0.4,0.45,0.5) | (0.5,0.5,0.5) | |
| P2 | Requirements Planning | (0.5,0.5,0.5) | | | | | 0.02307 |
| | Bidding procurement | (0.45,0.5,0.5) | (0.5,0.5,0.5) | | | | |
| | Contract management | (0.3,0.35,0.35) | (0.3,0.3,0.35) | (0.5,0.5,0.5) | | | |
| | Performance delivery | (0.5,0.55,0.6) | (0.45,0.5,0.55) | (0.7,0.7,0.6) | (0.5,0.5,0.5) | | |
| | Operation and maintenance | (0.5,0.5,0.55) | (0.4,0.45,0.45) | (0.7,0.65,0.65) | (0.45,0.45,0.5) | (0.5,0.5,0.5) | |
| P3 | Requirements Planning | (0.5,0.5,0.5) | | | | | 0.05910 |
| | Bidding procurement | (0.45,0.45,0.5) | (0.5,0.5,0.5) | | | | |
| | Contract management | (0.25,0.35,0.35) | (0.3,0.3,0.35) | (0.5,0.5,0.5) | | | |
| | Performance delivery | (0.55,0.6,0.6) | (0.5,0.5,0.55) | (0.8,0.8,0.8) | (0.5,0.5,0.5) | | |
| | Operation and maintenance | (0.6,0.6,0.6) | (0.45,0.5,0.55) | (0.75,0.75,0.7) | (0.45,0.55,0.6) | (0.5,0.5,0.5) | |
| P4 | Requirements Planning | (0.5,0.5,0.5) | | | | | 0.05218 |
| | Bidding procurement | (0.5,0.5,0.55) | (0.5,0.5,0.5) | | | | |
| | Contract management | (0.25,0.3,0.35) | (0.3,0.5,0.7) | (0.5,0.5,0.5) | | | |
| | Performance delivery | (0.45,0.5,0.55) | (0.45,0.5,0.55) | (0.65,0.75,0.8) | (0.5,0.5,0.5) | | |
| | Operation and maintenance | (0.5,0.55,0.6) | (0.4,0.45,0.45) | (0.6,0.7,0.8) | (0.5,0.5,0.55) | (0.5,0.5,0.5) | |

Table 3. First-level indicator weight

| Requirements Planning | Bidding procurement | Contract management | Performance delivery | Operation and maintenance |
|---|---|---|---|---|
| 0.20 | 0.21 | 0.16 | 0.22 | 0.21 |

Similarly, the weight value can be calculated for the second-level indicator under each first-level indicator. The final weight value is as follows (Table 4):

Table 4. Second-level indicator weight

| | | | |
|---|---|---|---|
| Centralized procurement rate | 0.07 | Prequalification completion rate | 0.06 |
| Accuracy rate of planed declaration | 0.04 | Qualification ability verification completion rate | 0.06 |
| Standardization rate | 0.09 | Bidding procurement success rate | 0.09 |
| Contract signing on-time rate | 0.09 | On-time delivery rate | 0.10 |
| Contract settlement completion rate | 0.07 | Sampling plan completion rate | 0.07 |
| Average malfunction response time | 0.09 | Average inspection time | 0.05 |
| Operation and maintenance plan completion rate | 0.06 | Information record integrity rate | 0.06 |

Calculate the first-level indicators synergy degree and overall synergy degree based on the relevant data of each company (Table 5):

Table 5. Synergy evaluation of each company

| | Requirements Planning | Bidding procurement | Contract management | Performance delivery | Operation and maintenance | Synergy degree |
|---|---|---|---|---|---|---|
| company1 | 0.336 | 0.244 | 0.402 | 0.316 | 0.895 | 0.440 |
| company 2 | 0.306 | 0.170 | 0.443 | 0.559 | 0.988 | 0.498 |
| company 3 | 0.344 | 0.261 | 0.429 | 0.763 | 0.865 | 0.542 |
| company 4 | 0.612 | 0.850 | 0.398 | 0.856 | 1.000 | 0.763 |
| company 5 | 0.446 | 0.323 | 0.545 | 0.536 | 1.000 | 0.572 |
| company 6 | 0.502 | 0.298 | 0.767 | 0.719 | 0.859 | 0.624 |
| company 7 | 0.387 | 0.315 | 0.987 | 0.833 | 0.455 | 0.580 |
| company 8 | 0.354 | 0.379 | 0.444 | 0.714 | 0.800 | 0.547 |
| company 9 | 0.543 | 0.240 | 0.459 | 0.788 | 0.673 | 0.547 |
| company 10 | 0.873 | 0.321 | 0.506 | 0.875 | 0.819 | 0.687 |
| company 11 | 0.370 | 0.200 | 0.608 | 0.788 | 0.984 | 0.593 |
| company 12 | 0.333 | 0.322 | 0.836 | 0.718 | 0.825 | 0.599 |
| company 13 | 0.336 | 0.295 | 0.671 | 0.844 | 0.433 | 0.513 |
| company 14 | 0.276 | 0.218 | 0.829 | 0.776 | 1.000 | 0.614 |
| company 15 | 0.330 | 0.275 | 0.574 | 0.754 | 0.988 | 0.589 |
| company 16 | 0.198 | 0.392 | 0.751 | 0.779 | 0.926 | 0.608 |
| company 17 | 0.710 | 0.286 | 0.627 | 0.753 | 0.786 | 0.633 |
| company 18 | 0.510 | 0.406 | 0.845 | 0.895 | 0.815 | 0.691 |
| company 19 | 0.365 | 0.218 | 0.668 | 0.702 | 1.000 | 0.590 |
| company 20 | 0.294 | 0.263 | 0.599 | 0.594 | 0.997 | 0.550 |
| company 21 | 0.500 | 0.311 | 0.606 | 0.612 | 0.350 | 0.470 |
| company 22 | 0.419 | 0.481 | 0.640 | 0.691 | 0.992 | 0.648 |
| company 23 | 0.322 | 0.289 | 0.887 | 0.791 | 0.591 | 0.565 |
| company 24 | 0.395 | 0.259 | 0.811 | 0.835 | 0.633 | 0.580 |
| company 25 | 0.479 | 0.288 | 0.816 | 0.828 | 1.000 | 0.679 |

By analyzing the evaluation values of each company's synergy degree, we can determine the synergetic weaknesses and make targeted adjustments.

## 5. Conclusion

Aiming at the problem of inter-departmental collaborative evaluation, this paper proposes an inter-departmental synergy evaluation model based on performance indicators. Starting from the inter-departmental synergy requirements, this paper select the performance indicators that can reflect the collaborative needs to establish a synergy evaluation index system, especially considering that the pre-order department work will affect the work efficiency of the post-order department, and select relevant performance indicators to join the evaluation index system. This model not only reflects the characteristics of inter-departmental synergy, but also provides new ideas for the design of departmental performance indicators.

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