**EVALUATION OF PROJECT LOGISTICS COMPANY SELECTION BASED ON CUSTOMERS’ PERSPECTIVES**

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1. **Introduction**

Logistics management in engineering, procurement, and construction (EPC) is an emerging business area that differs substantially from manufacturing logistics management, where the emphasis is on modelling volume production. Moreover, the organization and sourcing of materials are becoming increasingly complex across EPC industries due to both global sourcing of materials and the combination of advances in transport technologies and a shortage of professionals (O'Brien et al., 2009). At the same time, EPC customers are demanding faster, more responsive logistics processes and higher quality services. These demands generally involve both more responsive transportation and closer coordination between EPC and project logistics companies. For instance, a major EPC project places enormous demand on its logistics role, as arranging and organizing workers, materials, and equipment on such large scales is an important business. Nonetheless, when the logistics function is managed correctly in project logistics, it can contribute to EPC companies’ sustainable growth by affecting time, cost, quality, safety, and environmental performance among others (Mossman, 2008). Accordingly, a sound project logistics company selection can be seen as key to the successful transport of EPC cargo and to ensuring the competitiveness of EPC industries (Peng, 2012).

Despite the importance of project logistics in EPC industries, there is a lack of research on project logistics and its priority when EPC companies attempt to implement project logistics through project logistics company selection. To fill this gap, this study performs an empirical analysis focusing on the crucial factors used by EPC companies in project logistics company selection. This study seeks to help stakeholders and practitioners by analyzing the salient factors for project logistics company selection in EPC industries and draw relevant implications. The priority of project logistics company selection is analyzed using the fuzzy AHP method, after using the fuzzy Delphi method (FDM) with experts. Questionnaires are distributed to EPC companies’ employees. After the selection of preemptive evaluation factors by requesting an expert group to answer a questionnaire, the paper presents directions for project logistics company selection by analyzing the importance of and preference for the various selected factors. The rest of paper is structured as follows. The second section reviews the literature, and the third section explains the methodology. The empirical analysis is presented in the fourth section. Finally, the fifth section provides a discussion and presents concluding remarks.

2. **Literature review**

In terms of project logistics, a significant body of research has explored transport scheduling and efficiency. Most scholars adopt a service perspective focused on timely delivery (e.g., time performance, accuracy of transit/delivery time) (Garcia et al., 2012) and lower cost (e.g., price, cost reduction) (Jin et al., 2018). They also examine logistics capability by focusing on flexibility (e.g., ability to meet future requirement and capacity to adjust to customers' needs) (Naim et al., 2010) and risk management (e.g., risk prevention during natural disasters, piracy, and terrorism) (Rajesh et al., 2011). Further, project logistics companies’ experience, such as number of contracts (Sobotka et al., 2005) and infrastructure/equipment (Huo et al., 2008), were also analyzed. For example, according to Shi and Blomquist (2012), project scheduling is linked to the issues of resource handling, organizational structure, and behaviors of stakeholders that may affect the information split mechanism among different project partners. On the other hand, Jin et al. (2018) advanced a framework to map the effects of project management elements on project cost, and then tested the relationships between project management element and project cost for manufacturing construction projects.

Project logistics may be related to 3PL. A large body of literature explored 3PL transport efficiency (Hamdan and Rogers, 2008), service quality measuring (Gupta et al., 2017), and service quality improvement (Baligil et al., 2011) such as network optimization, and established the framework for measuring logistics performance. Percin (2009) argued that establishing a flexible and scalable logistics outsourcing network with 3PL providers is a key element in achieving lower costs, responsiveness to market, and enhanced flexibility. The results identified the model of 3PL provider selection can help stakeholders and practitioners understand the strengths and weaknesses of potential 3PL providers using evaluation criteria and sub-criteria.

Notwithstanding the extensive body of literature on project logistics and 3PL, there is a lack of research that integrates the various factors to be considered by EPC companies selecting project logistics companies. To fill this gap, this paper conducts an analysis to determine the priorities of EPC companies in selecting project logistics partners.

3. **Methodology**

**3.1 Fuzzy Delphi method**

In the selection of evaluative indicators, the FDM proposed by Hsu et al. (2013) is adopted to denote expert consensus using geometric means. The process is demonstrated as follows.

Step 1: Collect expert opinions using a decision group.

After identifying the relevant factors, *n* experts (decision makers) are invited to determine the importance of factors through a questionnaire using linguistic variables. This study applies triangular fuzzy numbers (TFNs) for evaluating the factors and a geometric mean model (Ma et al., 2011) to determine the experts’ group decision. The TFN *T ̃A* is as follows:

, *Eq. (1)*

,

where *i* indicates the *i*th expert, *i = 1, 2, …, n*; the factor’s weight of the *i*th expert for criterion *A*; the bottom of all the factor’s weight for criterion *A*; the geometric mean of all the factor’s weight for criterion *A*; and the ceiling of all the factor’s weight for criterion *A*.

Step 2: Geometric mean *MA* of each factor’s weight.

This step denotes the consensus of the expert group on the factor’s weight, so that the impact of extreme values could be avoided. For threshold factor r, the 80/20 rule is adopted, with r set as 8. This indicates that, among the factors for selection, “20% of the factors account for an 80% degree of importance of all the factors” (Kuo and Chen, 2008, p. 1934). The selection criteria are:

If *MA* > r = 8, this factor is accepted, *Eq. (2)*

If *MA* < r = 8, this factor is rejected.

For example, the timely delivery/reliability factor was awarded by each of the 10 experts 10, 9, 10, 10, 10, 10, 10, 10, 10, and 10:

*T ̃A*=(9,9.895,10),where *MA*>8, and this factor was accepted.

The other 22 factors were analyzed in the same way, with 16 factors identified by FDM ranking. The details are as shown in Table 2.

**3.2 Fuzzy set and fuzzy-AHP**

Relative criteria weights at the same level can be obtained using pairwise comparisons. A number of selected experts are approached to respond to questions such as “which criterion should be emphasized more in selecting a project logistics company, and how much more?.” The AHP procedure consists of the following steps (Ha and Yang, 2017; Saaty, 1980; Zeng et al., 2007).

Step 1: Define the pairwise comparison matrix.

TFNs are utilized for pairwise comparisons and to determine fuzzy weights because they are intuitively easy for decision makers to use and calculate. The computational process for fuzzy-AHP is detailed as follows. A TFN can be defined by triplet (*a1, a2, a3*) and the membership function *μA ̃(x)* is defined by:

. *Eq. (3)*

This paper uses nine basic linguistic terms with respect to a fuzzy nine-level scale. Each membership function (scale of a fuzzy number) is defined by three parameters of the symmetric TFN—the left, middle, and right points—of the range over which the function is defined.

Step 2: Establish a pairwise comparison of decision matrix A.

Let (*C1,C2,⋯,Cn*) denote the set of elements, while *aij* represents a quantified judgment on the pair of elements *Ci* and *Cj*. The relative importance of the two elements is rated using a measurement scale with values 1, 3, 5, 7, and 9, where 1 refers to “equally important,” 3 denotes “slightly more important,” 5 equals “strongly more important,” 7 represents “demonstrably more important,” and 9 denotes “absolutely more important.” This leads to an *n*-by-*n* comparison matrix *A*:

, *Eq. (4)*

Where,

Step 3: Define the fuzzy geometric mean and fuzzy weights.

Let *rijl* be the relative importance judgement on the pair of criteria *Ci* and *Cj* (*i,j=1,2,⋯,n*) by the *i*th expert. Then, the aggregated weight comparison between *Ci* and *Cj* by *m* experts (*l∈m*) can be obtained by:

. *Eq. (5)*

Next, the synthesized *i*th criterion weight comparison between *Ci* and *Cj* by m experts can be calculated using

. *Eq. (6)*

Step 4: Calculate consistency.

The relative weights, which would also present the eigenvalues of criteria are calculated as

 *Eq. (7)*

.

Another critical characteristic of AHP is the consistency of pairwise judgements by calculating the consistency ratio (CR) in Eq. (8). When the value of CR is greater than 0.1, an inconsistency in pairwise judgements appears and the experts need to revise their pairwise judgements. Therefore, the judgements should have an acceptable CR level of 0.10 or less.

, *Eq. (8)*

where CI is the consistency index, *λmax* the principal eigenvalue of the comparison matrix, RI the average random index, and *n* the number of criteria.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Size (*n*) | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| RI | 0 | 0 | 0.52 | 0.89 | 1.11 | 1.25 | 1.35 | 1.40 |

Table 1: Random consistency index

Step 5: Perform defuzzyfication and rank criteria.

The study determines the best crisp or non-fuzzy values in accordance with the center of area (COA) or center index (CI). The calculation method of the BNP value for each weight (*l, m, u*) is as follows:

*. Eq. (9)*

Finally, the criteria are ranked using BNP values. The criterion with a larger BNP value is considered to have a stronger effect compared to other criteria.

**3.3 Data collection and preparation**

Extant studies pertaining to project logistics were circulated among experts to obtain better insights into the problem. Due to the absence of a single directory for the respondents’ list, we crosschecked multiple directories, such as Korea Customs Logistics Association, Korea International Freight Forwarders Association, and Korea Integrated Logistics Association. Additionally, 10 experts from logistics companies, consisting of CEOs, general managers, and operations managers with professional experience, were selected. From October 15 to January 26, 2018, we interviewed 10 experts using the 23 factors obtained from the literature review. Based on the 80/20 rule, 16 detailed sub-criteria under the four main criteria (general service, logistics capability, organization characteristics, and organization resource) were identified.

The questionnaire was distributed to EPC companies that had project logistics company selection experience. From February 5 to March 9, 2018, 200 questionnaires were distributed; of these, 51 were returned. The response rate was approximately 26% and 47 valid questionnaires were used for analysis. The respondents ranged from CEOs to managers in business and logistics units. Therefore, a comprehensive and balanced view was ensured.

|  |  |  |  |
| --- | --- | --- | --- |
| No | Key factors (before: 23) | Geometric value | Key factors (after: 16) |
| 1 | Corporate reputation | 6.28 | Corporate scale  |
| 2 | Corporate scale  | 8.10 | Customer relationship management |
| 3 | Corporate social responsibility | 6.15 | Engineering technology |
| 4 | Customer relationship management | 8.06 | Experience  |
| 5 | Engineering technology | 8.88 | Financial stability |
| 6 | Experience  | 9.49 | Network/partnership  |
| 7 | Financial stability | 8.25 | Project logistics related transport vehicle |
| 8 | ISO compliance | 6.08 | Project logistics related unloading equipment |
| 9 | Know-how | 7.35 | Problem solving flexibility |
| 10 | Location | 5.24 | Reasonable cost |
| 11 | Loyalty | 6.31 | Risk management  |
| 12 | Network/partnership  | 8.17 | Skilled manpower |
| 13 | Project logistics related loading/unloading equipment | 8.46 | The provision of information technology |
| 14 | Project logistics related transport vehicle | 8.65 | Timely delivery/reliability |
| 15 | Problem solving flexibility | 9.69 | Transport route planner  |
| 16 | Professionalism | 7.74 | Worldwide office  |
| 17 | Reasonable cost | 9.18 |  |
| 18 | Risk management  | 8.07 |  |
| 19 | Skilled manpower | 8.31 |  |
| 20 | The provision of information technology | 8.02 |  |
| 21 | Timely delivery/reliability | 9.90 |  |
| 22 | Transport route planner  | 8.14 |  |
| 23 | Worldwide office  | 8.16 |  |

Table 2: Key factors before and after Delphi analysis

The overall objective of the decision process for project logistics company selection is at the first level of the hierarchy, the main criteria on the second level, and the sub-criteria on the third level. Details are as follows.



Figure 1: Hierarchical structure to selecting the best project logistics company

4. **Finding**

From the calculated criteria weight, the weighted evaluation matrix is constructed using Eqs. (3)–(9). The results are shown in Tables 3 and 4. The results of the general service criteria (M1) indicate timely delivery/reliability (GS4) is the most important factor, followed by reasonable cost (GS2), provision of information technology (GS3), and customer relationship management (GS1). In other words, decision making for project logistics company selection is made based on economic and timely accuracy when EPC companies make decisions. The results of the logistics capability criteria (M2) suggest problem solving flexibility (LC2) is the most important factor, followed by engineering technology (LC1), transport route planner (LC4), and risk management (LC3). It might be argued that factors such as the flexibility of problem solving for timely delivery and essential engineering technology are taken into consideration when EPC companies select project logistics companies in terms of logistics capability. The results of the organization characteristics criteria (M3) show experience (OC2) is the most important factor, followed by worldwide office (OC4), financial stability (OC3), and corporate scale (OC1). Project logistics company selection by EPC companies is sensitive to corporate experience for reliability of the project logistics company. Results of the organization resource criteria (M4) identify project logistics related loading/unloading equipment and transport vehicle (OR2 and OR3) are the most important factors, followed by skilled manpower (OR4) and network/partnership (OR1). Finally, the results of the priority importance of the sub-criteria (Table 10) are as follows. Table 10 shows timely delivery/reliability (GS1) is the most important factor, followed by problem solving flexibility (LC2), experience (OC2), and reasonable cost (GS2).

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Major criterion | Consistency | Major criterion weight | Major criterion BNP | Ranking |
| General service | 0.092 | (0.251, 0.298, 0.349) | 0.299 | 1 |
| Logistics capability | (0.216, 0.254, 0.298) | 0.256 | 2 |
| Org. characteristics | (0.110, 0.130, 0.156) | 0.132 | 4 |
| Org. resource | (0.145, 0.169, 0.197) | 0.170 | 3 |

Table 3: Ranking of main criteria for project logistics company selection

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Sub-criterion | Consistency | Sub-criterion weight | BNP | Ranking | Total ranking |
| GS1 | 0.010 | (0.081, 0.092, 0.105) | 0.093 | 4 | 16 |
| GS2 | (0.251, 0.289, 0.330) | 0.290 | 2 | 4 |
| GS3 | (0.137, 0.156, 0.181) | 0.158 | 3 | 11 |
| GS4 | (0.289, 0.336, 0.384) | 0.336 | 1 | 1 |
| LC1 | 0.020 | (0.233, 0.279, 0.330) | 0.281 | 2 | 5 |
| LC2 | (0.265, 0.313, 0.362) | 0.313 | 1 | 2 |
| LC3 | (0.090, 0.105, 0.124) | 0.106 | 4 | 15 |
| LC4 | (0.127, 0.151, 0.184) | 0.154 | 3 | 12 |
| OC1 | 0.020 | (0.128, 0.147, 0.172) | 0.149 | 4 | 14 |
| OC2 | (0.256, 0.304, 0.356) | 0.305 | 1 | 3 |
| OC3 | (0.151, 0.176, 0.205) | 0.177 | 3 | 10 |
| OC4 | (0.194, 0.227, 0.267) | 0.229 | 2 | 9 |
| OR1 | 0.010 | (0.127, 0.150, 0.179) | 0.152 | 4 | 13 |
| OR2 | (0.201, 0.235, 0.277) | 0.238 | 1 | 6 |
| OR3 | (0.196, 0.230, 0.271) | 0.232 | 2 | 7 |
| OR4 | (0.192, 0.230, 0.273) | 0.232 | 3 | 8 |

Table4: Ranking of sub-criteria for project logistics company selection

5. **Concluding remarks**

To the best of our knowledge, this study is the first to uncover the project logistics company selection of the EPC companies. This is the most powerful motivation to consider this issue. As such, this study may enhance the better grasp of the importance of project logistics company selection of EPC companies and provide the stakeholders and practitioners with meritorious insights. This paper may also provide a clear understanding of the EPC companies’ needs regarding project logistics company selection. Additionally, by benchmarking the results, project logistics managers can determine how to provide efficient services and make prompt adjustments to meet their customers’ needs.

The five top-ranked factors include two factors under general service criteria (GS2 and GS4), two factors under logistics capability criteria (LC1 and LC2), and one factor under organization characteristics criteria (OC2). These results might help decide the direction of decision making for project logistics company selection. As the criteria in general service (M1) are considered to be the most important factors, the more involute and difficult the problem, the more the number of analytical and rational factors that need to be considered. Because the problem with project logistics is in managing the time factor, which represents a set of constraints for logistics (Sandhu, 2006), the most important factor is timely delivery and reliability (GS4). Remarkably, although the literature did not focus on project logistics related loading/unloading equipment (OR2) and transport vehicle (OR3), this study found these factors have high priority. The results suggest project logistics selection is slightly different from 3PL selection and other service providers. Because it needs to acquire specialized equipment (e.g., module transporter) and transport vehicles (dedicated vessels, multi-module trailers, barges for heavy cargoes) for the transportation of EPC cargoes, it is an important factor. Thus, this paper might provide valuable insights for strategies, service capability, and sustainable growth as to meet customers’ needs in EPC companies through selecting suitable project logistics companies.

Despite the superiority of this study over previous ones, it has some limitations. It has been difficult for decision makers involved in project logistics company selection to obtain reliable and stable data on their decision making and judgments. Therefore, it will be necessary to obtain more accurate results by securing a variety of objective data through more in-depth interviews and surveys.

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