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Model for Evaluating Outsourcing Logistics Companies in the COVID-19 Pandemic

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Abstract: The COVID-19 pandemic has severely affected the world's manufacturing industry, particularly in terms of the continued increase in logistics costs that has led to an increase in business operating costs. This study proposes a two-stage model for evaluating the most appropriate outsourcing logistics companies for a manufacturing factory. In the first stage, a modified Delphi method was used to recruit experienced experts to determine criteria for evaluating outsourcing logistics vendors and establish a hierarchical structure. In the second stage, the analytic hierarchy process (AHP) was used to evaluate suitable logistics companies based on the hierarchical structure. Finally, a case study was conducted to demonstrate the suitability of the two-stage model for evaluating outsourcing logistics companies for reducing logistics costs while maintaining service quality. The proposed model can be used as a basis for evaluating outsourcing logistics companies.

Keywords: logistics; outsourcing; Delphi method; analytic hierarchy process; COVID-19 pandemic



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1. Introduction

In 2007, the total output value of the Hsinchu Science Park was approximately TWD 1.14 trillion, accounting for one-tenth of Taiwan's total industrial output value. Therefore, scholars have studied strategies for protecting its output value. Wang and Sun [1] used Taiwan's 2002–2007 influenza notification data to simulate the effects of public health policy interventions and recommended that the Central Epidemic Command Center should promptly implement appropriate strategies to reduce the effect of new influenza outbreaks on the Hsinchu Science Park, thus ensuring Taiwan's economic growth and technology industry development. Xu et al. [2] reported that the 2002–2004 severe acute respiratory syndrome (SARS) epidemic caused a decline in the output value of almost all industries in Taiwan and engendered an increase in the number of unemployed people. Moreover, the epidemic caused a 0.84 to 1.61% reduction in Taiwan's GDP. The World Trade Organization announced that the epidemic disrupted supply chains and severely affected global trade activities [3]. The global trade volume was expected to decrease by 12.9%. Taiwan's GDP growth rate in 2020 was 2.98%. However, Taiwan's GDP is expected to increase by 4.64% because of the implementation of the pandemic prevention policy: “Three Don'ts” (don't lose your temper, don't worry, and don't be anxious) and “Five Dos” (wash your hands frequently, drink more warm water, do more exercise, be happy, and be more careful) [4,5].

Liu [6] reported that the COVID-19 pandemic and investment and technology sanctions imposed by the United States on mainland China have accelerated the migration of the supply chain from China to the rest of the world. Taiwan's science parks have a

complete technology industry cluster. At the same time, benefiting from the COVID-19 epidemic and the Sino-US trade war, global electric vehicle demand, digital transformation, remote work, and distance learning, the global semiconductor market will reach USD 440.4 billion in 2020, an annual increase of 6.8% [7–9]. Pan [10] reported that Taiwan is an export-oriented country. Taiwan defended against the epidemic in 2019, seized global 5G and AI business opportunities, and capitalized on the demand for semiconductor products. The turnover of science parks reached TWD 3.276 trillion (TWD 1 is equivalent to USD 0.0357), an increase of approximately 15% over 2019. Among them, the output value of semiconductors in 2020 will increase by 20.9% compared with 2019, and it is expected to increase by 3.5% in 2021, reaching TWD 3.33 trillion. The total number of employees in all science parks has also increased by 3% over 2019, to 288,237 [11].

According to the Taiwan Stock Exchange [12], the continual spread of COVID-19 and the “explosive rebound” of demand from European and American markets for Asian exports have caused a severe imbalance between supply and demand in the container shipping market, leading to an increasingly severe shortage of containers and ships. For the logistics industry, extreme market changes have occurred, resulting in a problem of container supply and demand. Moreover, international freight rates have increased by 3–10 times, causing overwhelming orders for global logistics service contractors.

The success of the Hsinchu Industrial Science Park is another achievement in Taiwan after the rapid economic growth following the COVID-19 pandemic. Sun [13] indicated that science parks provide a crucial resource network for high-tech industries. Siagian et al. [14] proposed that in the COVID-19 era, supply chains must integrate flexibility and innovation to improve company operating performance. Scholars have increasingly shown interest in analyzing the growth of science parks globally [15–17]. Outsourcing is a success factor for science parks [18]. Enterprises outsource not only production components and services but also knowledge and manpower. Accordingly, logistics centers have become an effective means of efficiently managing the commercial activities of enterprises. Services related to customer service, logistics centers, information systems, logistics organization, strategic planning, and overall integrated operation have been integrated into the management of enterprise commercial activities.

Taiwan is a crucial export destination for global high-tech industries. During the COVID-19 pandemic, some airlines declared bankruptcy, and global airlines can depend on only government support to survive the crisis [19]. In the maritime sector, entire ships must be disinfected along with the implementation of strict logistics customs quarantine measures. Moreover, prolonged transportation time can delay the import and export of goods, causing the shortage of materials and labor in the global manufacturing industry and eventually leading to a broken production chain and delayed schedules. Issues such as shipping regulations and unmet market demands have brought the global manufacturing industry into a critical moment of survival [20]. This study presents a two-stage evaluation model for assessing outsourcing processes in the logistics industry. The first stage involves the use of the modified Delphi method to identify the most appropriate evaluation criteria [21]. The second stage involves the adoption of an analytic hierarchy process (AHP)-based high-tech industry decision-making method to objectively evaluate the quality of a logistics technology supplier when outsourcing logistics needs; this method can serve as an alternative to subjective decision-making approaches [22].

The rest of this paper is organized as follows: Section 2 presents the literature review. Section 3 describes the group decision-making process, Delphi method, and AHP method. Section 4 presents the selection model, in which evaluation criteria are developed through a group decision-making process with the Delphi method, weight values are calculated, and the AHP method is used to construct the evaluation model. The section also presents the use of the proposed AHP model for the selection of the most appropriate logistics company for the high-tech industry. The main results and conclusions, study limitations, and future research directions are provided in Section 5.

2. Literature Review

This section comprises two parts: Section 2.1 presents a discussion of studies on transport and logistics outsourcing, and Section 2.2 provides a discussion of studies on the use of multicriteria decision-making (MCDM) in the evaluation of logistics providers.

2.1. Transport and Logistics Outsourcing

Although an increasing number of companies are outsourcing transport and logistics processes, the failure rate of such outsourcing efforts is considerably high. Using data collected from 250 manufacturing companies in China, Yuan et al. [23] developed transaction cost theory and adopted the resource-based view to determine success factors (asset specificity, technological uncertainty, top management beliefs, supplier presence, and outsourcing success) for logistics outsourcing. Ellram and Siferd [24] suggested dividing the total costs of enterprises according to attitude, management, product delivery, service, communication ability, retail price, and quality. Logistics has become an effective means of managing the commercial activities of enterprises [25]. Lorence and Spink [26] and Ellram and Maltz [27] have suggested that the total cost of ownership substantially affects outsourcing decisions. Furthermore, Lim and Palvia [28] revealed that many interorganizational systems are increasingly applying electronic data interchange to support the strategic supply chain by delivering and processing business documents. Yan and Zhang [29] suggested that integrated services include those related to customer service, logistics centers, information systems, logistics organization, strategic planning, and overall integrated operations. Aktas and Ulengin [30] examined logistics functions outsourced by Turkish firms, including the extent to which logistics and transportation functions are outsourced, and criteria used to select and evaluate the performance of outsourcing firms. The number of logistics companies that outsource their functions has increased rapidly, positively affecting the quality of services and efficiency as well as complying with consumer demands. Reyes et al. [31] reported that outsourcing enables firms to enhance their information system services and departments. By outsourcing their logistics needs, enterprises can enhance their corporate performance by strengthening the competitiveness of their supply chain. Supply chain managers can assess success factors for the logistics sector and e-commerce. White et al. [32] reported that supply chain managers must accept uncertainty by developing a strategy that can be enhanced through supply and demand at an acceptable cost. Su [33] suggested that under supply chain management, the internal operations of a company or all logistics services must identify specialized divisions of labor to enhance corporate performance and market competitiveness. An enterprise operating under a supply chain structure that lacks logistics-oriented management skills and technical support would experience decreased competitiveness and encounter potential elimination from the market. Yang and Huang [34] and Richard and Kathryn [35] have indicated that essential information system skills can be enhanced by developing superior capabilities in information systems to increase operations and gain a competitive advantage. Transaction costs, strategy, economics, technology, and quality are determinants of enhanced information system management.

2.2. MCDM in the Evaluation of Logistics Providers

Divahar and Sudhahar [36] used quality, reverse logistics cost, delivery, and technology capability as criteria and applied the AHP to evaluate the selection of reverse logistics providers. Peng [37] used the AHP to analyze the characteristics of outsourcing providers in the logistics industry; they used evaluation indices such as logistics cost, logistics operation efficiency, basic service suppliers' quality, and logistics technology level and examined targetability and practicability of such indices. In addition to preventing unnecessary risks, reducing overhead costs, and improving service quality, an AHP evaluation model and several evaluation criteria can be incorporated for large-scale high-tech corporations outsourcing their logistics needs [38]. The adoption of the AHP for establishing an evaluation model for the high-tech industry can help determine not only the effectiveness

of logistics companies in outsourcing their logistics needs but also various criteria (cost competitiveness, human resources, business, economic environments, government policies, and legal framework) and their weight values; this can further help in setting priorities and ultimately selecting the best alternative [39]. Secundo et al. [40] used a fuzzy AHP method to evaluate the selection of service suppliers. Baidya et al. [41] indicated that logistics centers can effectively manage the strategic techniques and commercial activities of enterprises. Integrated services adopted include those related to customer service, logistics centers, information systems, logistics organization, strategic planning, and overall integrated operations. The demand for logistics outsourcing services in the high-tech sector has increased substantially. Falsini et al. [42] combined the AHP, DEA, and linear programming to evaluate the multicriteria evaluation of third-party logistics service providers. Govindan et al. [43] combined grey decision-making trial and evaluation laboratory (DEMATEL) methods to establish selection criteria for third-party logistics providers. Vieira et al. [44] considered distribution strategies, internal activities, and distribution operation characteristics in the AHP to develop an evaluation framework for large logistics providers. Xiaomin et al. [45] used an AHP method based on the SERVQUAL model to examine customer satisfaction with a third-party logistics enterprise. Singh et al. [46] used the fuzzy AHP and fuzzy technique for order preference by similarity to ideal solution (TOPSIS) and Ortiz-Barrios [47] used the AHP, DEMATEL, and TOPSIS to develop a food supply chain model for the selection of third-party logistics services. Zhao et al. [48] considered integrating food safety, quality, and finance as factors into the supply chain of agricultural product processors and suppliers and consumer logistics providers. Lorence and Spink [26] reported that managerial decisions involving information system outsourcing can lead to enhanced patient care, cost savings, regulations, competition, trained staff availability, and space considerations. Foulds and Luo [49] found that production transformation and reverse logistics are the most commonly offered services. However, further utilization of vendor-managed inventory and cross-docking is necessary. Finally, information technologies are widely utilized in third-party warehousing [50–54]. Hadian et al. [55] compared the AHP–BOCR (benefits, opportunities, costs, and risks) method with the VIKOR (Vlsekriterijumska Optimizacija I Kompromisno Resenje, in Serbian)–AHP–BOCR method to choose the best external providers of galvanized steel sheets used in car fabrics. They found that the VIKOR–AHP–BOCR method could provide a compromise option, which is closer to the ideal decision-making option. On the basis of the analytical network process (ANP) and quality function deployment (QFD), Karami et al. [56] developed criteria involving cost, punctuality, efficacy, programming, and availability to evaluate suppliers. Bottani et al. [57] combined the ANP and QFD in their decision model to evaluate suppliers for purchasing. QFD approaches can define suppliers' characteristics, and the ANP can examine interrelations among selection criteria when integrated with a BOCR analysis. Table 1 lists MCDM methods used to select suppliers in previous studies.

According to the literature review, enterprises must carefully implement division of labor through the outsourcing of logistics requirements. Companies that outsource their logistics needs can improve productivity through supply chain management and ultimately enhance their competitive advantage. However, when a company decides to adopt a logistics system, technical skills and cost-related factors are primary concerns. If outsourcing is deemed necessary, rigorous measures must be implemented during the selection of a provider that outsources its logistics needs. Business managers attempt to reduce operating costs to increase the overall value of the company. They must evaluate how to reduce costs associated with outsourcing requirements and verify the effectiveness of outsourcing operating procedures. The proposed AHP-based decision-making method can help high-tech managers establish decision-making and evaluation criteria and actively encourage logistics departments to outsource to logistics contractors. To establish such criteria and weights, this study integrated group decision-making and the Delphi method in a questionnaire survey to help logistics experts in Taiwan's high-tech industry to reach group consensus. The group consensus was used as the basis to propose the most appro-

appropriate supplier evaluation criteria and weight values. In addition, a private practitioner provided their personal opinions through a resubmitted questionnaire until a consensus was reached.

Table 1. MCDM methods for evaluating the related references of supplier selection.

Author/Year	Methods	Case Study	Criteria
Divahar and Sudhahar (2012)	AHP	Evaluation and selection of the most appropriate reverse logistics provider	Quality, reverse logistics cost, delivery, and technology capability
Peng (2012)	AHP	Frozen food industry for the evaluation and selection of logistics outsourcing service suppliers	Logistics cost, logistics operation efficiency, basic qualities of service suppliers, and logistics technology
Chen et al. (2013)	AHP	Evaluation and selection of outsourcing destinations in East and Southeast Asia	Cost competitiveness, human resources, business and economic environments, government policies and legal framework
Gupta et al. (2017)	AHP	Outsourcing the supply chain and logistics operations of organizations to third-party logistics providers	Assets, processes, and services
Baidya et al. (2018)	QFD and AHP	Manufacturing organizations depend on the reliability and productivity of equipment, machinery, and the entire manufacturing system	Return on investment, running cost, reliability, operability, flexibility, machine availability safety, resource utilization, and energy consumption
Falsini et al. (2012)	AHP, DEA, and linear programming	Evaluation and selection of a logistics provider	Industry and defense, perishable products, and consumer goods
Govindan et al. (2016)	Grey decision-making, DEMATEL	Selection of a third-party logistics provider for Iran's automotive industry	Time delivery performance, technological capability, financial stability, human resource policies, service quality, and customer service
Vidal Vieira et al. (2017)	AHP	Logistics operations in retail distribution centers	Receiving, put-away, picking, shipping, and cost
Xiaomin and Yi (2017)	AHP	Evaluation index system for customer satisfaction of 3PL enterprises in Hong Kong	Shipping, air transport, multimodal transport, warehousing and logistics, trailers, commodity inspection, insurance, and cargo packaging
Singh et al. (2018)	Fuzzy AHP and Fuzzy TOPSIS	Cold chain industry in India for the selection of third-party logistics providers	Transportation and warehousing cost, logistic infrastructure and warehousing facilities, customer service and reliability, network management, material handling capabilities, quality control and inspection, automation of processes, innovation and effectiveness of cold chain processes, IT applications for tracking and tracing, and flexibility of processes
Ortiz-Barrios et al. (2019)	AHP, DEMATEL, and TOPSIS	Food supply chain management	Quality, commercial profile, innovation, production capacity, service level, localization, and financial profile
Hadian et al. (2020)	VIKOR and BOCR	Selection of the best providers of galvanized steel sheets for Iran Khodro	Benefits, opportunities, costs, and risks
Karami et al. (2015)	QFD and ANP	Supplier selection based on quality	Quality, cost, timely delivery, efficiency, accessibility and customer protection, and deliverable planning
Bottani et al. (2018)	QFD and ANP	Evaluate and select the best supplier for an Italian company	Benefits, opportunities, costs, and risks

3. Methodology

The COVID-19 pandemic is changing rapidly. To respond to the pandemic, the high-tech industry should react rapidly. Therefore, by adopting the AHP method, companies can choose experts in transportation, customs declaration, and epidemic fields to systematize complex issues. When a hierarchical structure of mutual influence is established, complex issues and risks can be easily resolved. Companies should strive to be consistent in

making judgments regarding different situations and should comprehensively evaluate these quantitative judgments to provide adequate information for decision-making and reduce the risk of choosing an inappropriate outsourcing logistics company.

This study included experts from major high-tech and logistics companies that had tax-exempt status in Taiwan's Hsinchu Industrial Science Park during the COVID-19 pandemic. The modified Delphi method and AHP were used to construct a two-stage model for evaluating and selecting logistics companies. Figure 1 shows the flowchart of the two-stage model.

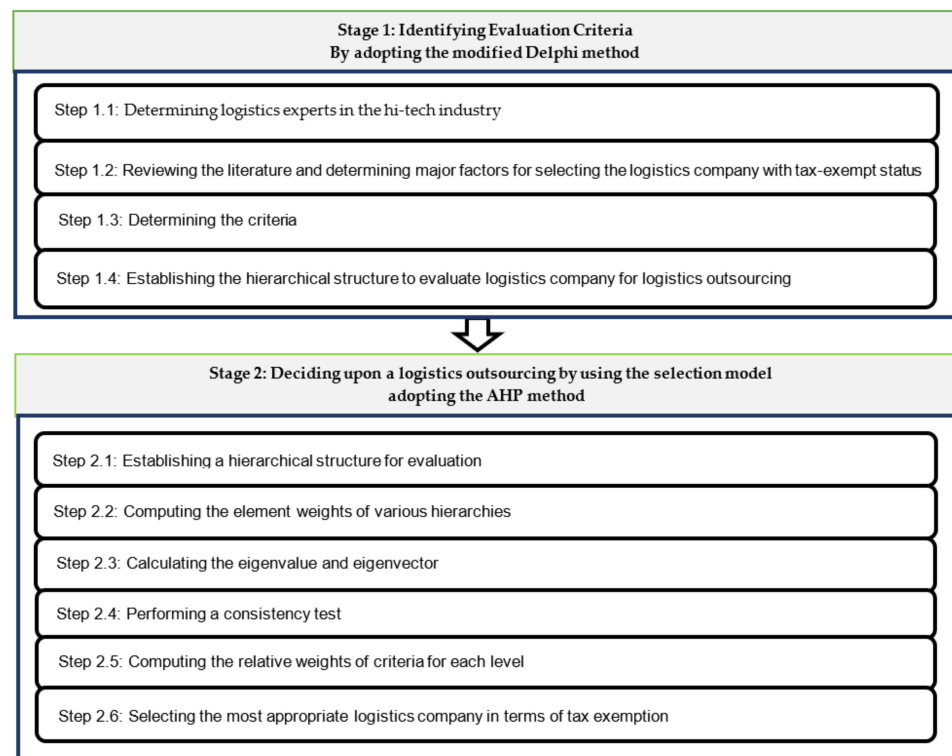


Figure 1. Outsourcing model for evaluating and selecting a logistics company.

Stage 1: The modified Delphi method [58–61] was used to accumulate and integrate expert opinions. Subsequently, normal evaluation criteria were determined. The steps involved in the modified Delphi method are outlined as follows: Step 1.1: determining logistics experts in the high-tech industry, Step 1.2: reviewing the literature and determining major factors for selecting logistics companies with tax-exempt status, Step 1.3: establishing the criteria, and Step 1.4: establishing the hierarchical structure to evaluate logistics companies for outsourcing to the next stage of the AHP hierarchical structure [62].

Stage 2: The AHP [62] was used to establish a model for selecting the most qualified logistics company for the high-tech industry. The steps involved in the AHP process are outlined as follows:

Step 2.1: Establishing a hierarchical structure for evaluation

According to the conclusions of Stage 1 Step 1.4, the evaluation hierarchy and evaluation criteria of outsourcing logistics of the high-tech industry in Hsinchu Science Park are established.

Step 2.2: Computing the element weights of various hierarchies

Let C_1, C_2, \dots, C_n be the set of evaluation criteria, while a_{ij} represents a quantitative judgment on a pair of criteria C_i, C_j . An n by n matrix A can be gained as follows:

$$A = [a_{ij}] = \begin{matrix} & \begin{matrix} C_1 & C_2 & \dots & C_n \end{matrix} \\ \begin{matrix} C_1 \\ C_2 \\ \vdots \\ C_n \end{matrix} & \begin{bmatrix} 1 & a_{12} & \dots & a_{1n} \\ 1/a_{12} & 1 & \dots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \dots & 1 \end{bmatrix} \end{matrix} \quad (1)$$

Pairwise comparison results of the n criteria are inserted into the upper triangle of matrix A . The principal diagonal criteria are oneself to oneself compared outcomes. Therefore, their outcomes are 1.

Step 2.3: Calculating eigenvalues and eigenvectors

The pairwise comparison matrix λ_{max} comprises the maximum eigenvalues of A [56]. When A is a consistency matrix, the eigenvector x can be calculated using Equation (2).

$$(A - \lambda_{max}I)x = 0 \quad (2)$$

$$\lambda_{max} = \sum_{j=1}^n a_{ij} \frac{W_j}{W_i} \quad (3)$$

where x is the eigenvalue of the eigenvector and a_{ij} is the subjective judgment of the comparison and appraisal provided by decision-makers, with the actual value ($\frac{W_j}{W_i}$) having a certain degree of variation.

Step 2.4: Performing a consistency test

Consistency index (CI) and consistency ratio (CR) are used to verify the consistency of the comparison matrix [56]. CI and CR are defined as follows:

$$CI = (\lambda_{max} - n) / (n - 1) \quad (4)$$

$$CR = CI / RI \quad (5)$$

where RI indicates the random index, and fixed values regarding RI are given in Table 2 [62]. When $CR \leq 0.1$, A is consistent, or its degree of inconsistency is acceptable.

Table 2. RI based on the dimensions of pairwise matrix A .

Number	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Step 2.5: Computing the relative weights of criteria for each level

Step 2.6: Calculating the overall hierarchy weight for selecting the most appropriate logistics company in terms of tax exemption [62].

4. Results

During the COVID-19 pandemic, Taiwan's Hsinchu Science Park provided crucial key components and resource networks for the global high-tech industry. Logistics information technology, service quality, and cost are key elements to ensure the stable shipment of products during the pandemic. In the proposed two-stage evaluation model, the first stage comprises four steps, which entail the use of the modified Delphi method to identify the most appropriate evaluation criteria. The second stage involves six steps, which entail the use of the AHP to calculate the weights of the decision-making evaluation criteria and to evaluate the effectiveness of the logistics company in adopting the tax exemption model.

Stage 1: Identifying evaluation criteria

The modified Delphi method was used to establish evaluation criteria for selecting an appropriate logistics company on the basis of expert consensus. Criteria for outsourcing logistics and subcriteria for a logistics system for the high-tech industry were then evaluated using the group decision process of the modified Delphi method. Subsequently, through

the use of a questionnaire, decision-making attributes were derived to evaluate tax-exempt logistics companies. In addition, the improved Delphi method was used to determine the preferences of group members and reach group consensus. Moreover, expert interview results were integrated with the AHP to establish an objective evaluation criterion for the logistics company.

Step 1.1: Determining logistics experts in the high-tech industry

The logistics service part includes land transportation, storage, loading and unloading, packaging, circulation processing, distribution, customs declaration, sea and air transportation, and other services. On the basis of experts' opinions, we can assist the high-tech industry in the Hsinchu Science Park in solving logistics problems. The shipment must reach the client on schedule.

Eight logistics experts were selected from companies in the high-tech industry on the basis of the following criteria were selected: (1) the high-tech company must be in operation for at least 3 years, (2) logistics experts must have participated in logistics decision-making previously, and (3) logistics experts must be qualified to practice in the high-tech industry such as in logistics departments. The eight logistics experts comprised two managers, one division chief, two assistant managers, one procurement manager, one imports and exports assistant manager, and one supervisor.

Step 1.2: Reviewing the literature and determining major factors for selecting a logistics company with tax-exempt status

Because of COVID-19, the governments of various countries have provided companies with varying degrees of tax cuts or exemptions, accelerated export tax rebates, or implemented tax reduction policies. The Taiwanese government also has related policies. However, in Taiwan, companies must submit relevant certificates to the government to apply for exemptions, rather than the government taking the initiative to implement exemptions. Even if the government had a tax exemption policy, companies would still not be able to obtain tax reductions or exemptions if they do not apply. Considering the operating costs of high-tech factories in the Hsinchu Science Park, this study evaluated the most suitable logistics companies to obtain complete tariff information regarding Taiwan and other countries; such information can help high-tech factories export and reduce their costs.

This study identified crucial factors for the selection of logistics companies for outsourcing. The literature on logistics evaluation criteria includes studies on logistics sector sources and conforms to the experts in the decision-making group.

These factors are outlined as follows: (1) the development and implementation of a logistics company's expert system conform to the current tax-exempt status and technology trends and practices, (2) the logistics company complies with a clearly defined software engineering standard such as a system specification book and system test plan and record, and (3) the logistics company adheres to the high-tech industry's requirements.

Closely examining the customer status can enable a logistics company to enhance its collaborative potential. Regarding service-related factors, computer companies can provide sufficient human resources, professional experience, and technical expertise. Moreover, logistics companies adhere to a service management system that is equally vital. Furthermore, the after-sales service provided by a logistics company can enable a firm to gain a foothold in a specific service region.

Step 1.3: Determining the criteria

A 5-point Likert-type scale was used to calculate the weights of the criteria; such weights were used as a crucial reference. In addition, high-tech sector administrators were invited to select appropriate logistics companies on the basis of the evaluation factors.

Step 1.4: Establishing a hierarchical structure to evaluate logistics companies for outsourcing

As shown in Figure 1, the experts established an essential criterion after analyzing the results of three rounds of survey to determine the hierarchical structure.

Stage 2: Deciding upon logistics outsourcing by using the selection model

An AHP-based survey was designed using a pairwise comparison method to determine logistics outsourcing demand scores for each item. Moreover, each criterion and rank were required to pass the consistency test for inclusion in the AHP-based decision-making model. Finally, the group experts' contributions and opinions were used along with the AHP to calculate weights and optimum alternatives. A total of 13 available experts were invited to participate in this study in April 2021. The experts were selected from government units, manufacturers, and logistics companies in the Hsinchu Science Park. Among the experts, two were from the Hsinchu Science Park Administration (one was responsible for customs duties and the other was responsible for bailout benefits during COVID-19), two were senior managers responsible for import and export business for at least 5 years, two were senior managers responsible for the logistics department for at least 5 years, two were managers responsible for purchasing for at least 5 years, and five were senior managers in logistics companies. The AHP method used in this study, the mathematical formulas used in the calculation process, and the scale used by the experts were described previously [56].

Step 2.1: Establishing an evaluation hierarchy structure

For a logistics company with tax-exempt outsourcing, the hierarchical structure included the goal, criterion, subcriterion, and alternative levels (Figure 2).

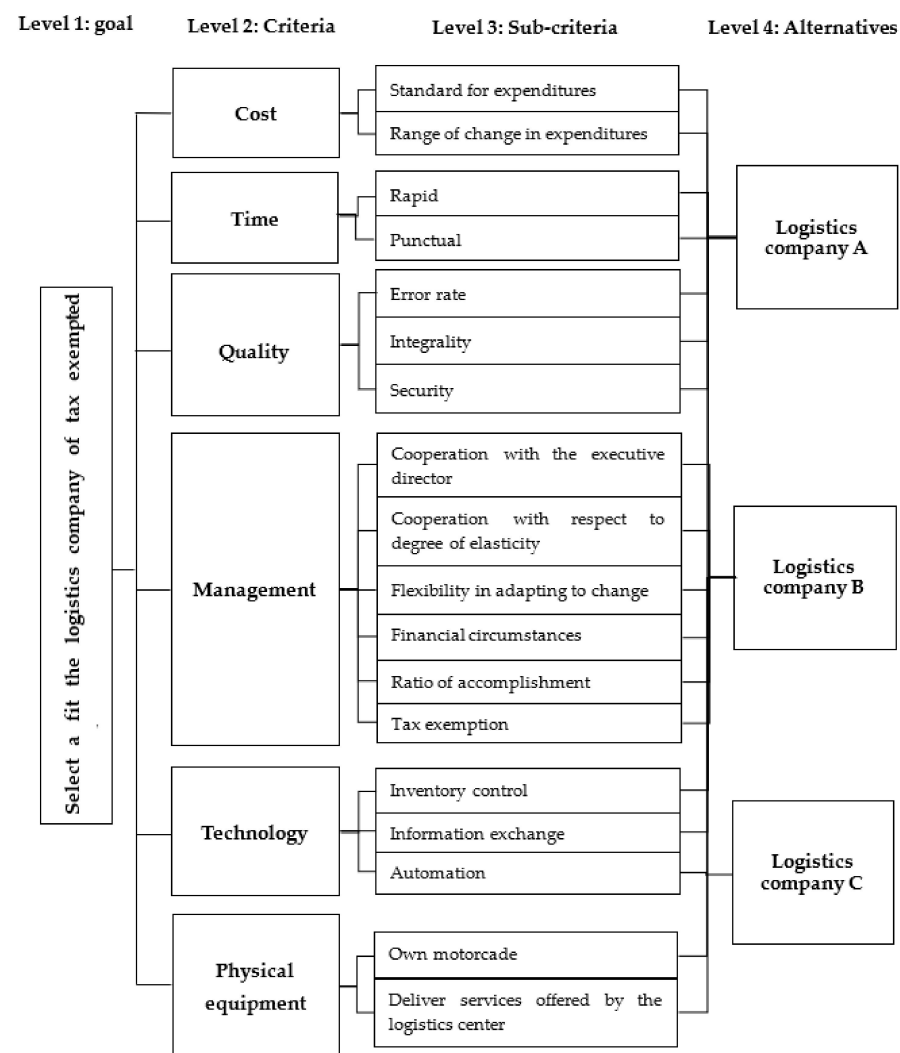


Figure 2. Hierarchical structure required to select the most appropriate logistics company with tax exemption status.

Step 2.2: Computing the element weights of various hierarchies

The geometric mean of the weight values derived by the eight experts was used to calculate the experts' overall decision-making score. Thus, standard weight values were derived, and an appropriate logistics company with a tax-exempt status was selected. For example, the main criteria were formed as a sample (Table 3).

Table 3. Aggregate pairwise comparison matrix for the criteria of level 2.

Level 2 Criteria	Cost	Time	Quality	Management	Technology	Physical Equipment
Cost	1.000	0.424	0.482	0.753	0.843	1.677
Time	2.360	1.000	0.491	0.963	2.105	2.210
Quality	2.073	2.036	1.000	1.459	2.329	1.576
Management	1.327	1.038	0.685	1.000	1.107	1.403
Technology	1.187	0.475	0.429	0.903	1.000	1.348
Physical equipment	0.596	0.452	0.634	0.713	0.742	1.000

$$\lambda_{\max} = 6.2836; C.I. = 0.057 < 0.1; R.I. = 1.24; CR = 0.0459 \leq 0.1.$$

Step 2.3: Calculating the eigenvalue and eigenvector

Equations (2) and the comparison matrix (see Table 4) were used to calculate the weights for the subcriteria, overall weights, and eigenvectors. Table 3 lists the dominant values of the three alternatives and the results of the eigenvectors of each criterion and subcriterion.

Table 4. Weights of criteria and subcriteria.

Criteria	Weights of Overall Levels	Subcriteria	Weight of Subcriteria
Cost	0.156	Standard for expenditures	0.667
		Range of changed in expenditures	0.333
Time	0.200	Rapid	0.400
		Punctual	0.600
Quality	0.178	Error rate	0.250
		Integrity	0.350
		Security	0.400
Management	0.165	Cooperation with the executive director	0.087
		Cooperation with respect to degree of elasticity	0.137
		Flexibility in adapting to change	0.196
		Financial circumstances	0.109
		Ratio of accomplishment	0.224
		Tax exemption	0.248
Technology	0.154	Inventory control	0.550
		Information exchange	0.220
		Automation	0.230
Physical Equipment	0.147	Own motorcade	0.333
		Deliver services offered by the logistics center	0.667

Step 2.4: Performing a consistency test

A consistency test was performed by Equations (3) and (4) to examine the comparison matrix for each hierarchy, and the results revealed a consistency index (CI) of ≤ 0.1 and a consistency ratio of ≤ 0.1 for the comparison matrix from each of the nine experts [53].

Step 2.5: Computing the relative weights of elements for each level

Table 3 presents a summary of the relative weights of the elements of each level. According to this table, while selecting a tax-exempted logistics company, stakeholders in the high-tech sector would consider the following factors (in order): time (0.200) > quality (0.178) > management (0.165) > cost (0.156) > technology (0.154) > physical equipment (0.147). The evaluation results for the subcriteria are described as follows:

- (1). The high-tech sector is a semiclosed organization. Therefore, the punctuality of an organization (0.600) and the rapid pace of time (0.400) were determined to be crucial criteria for a logistics company.
- (2). According to private enterprises, quality and security (0.400), the vital subcriterion, constituted the second most important criterion for a logistics company, followed by integrality (0.350) and error rate (0.250).
- (3). Regarding services, costs must have a standard for expenditures (0.667) and a range of change in expenditures (0.333).
- (4). Regarding the criteria for the logistics supplier's technology, inventory control (0.550) was the most crucial criterion, followed by automation capabilities (0.230) and information exchange (0.220).
- (5). Regarding the management of a logistics company, tax exemption was the most crucial criterion (0.248), followed by the ratio of accomplishment (0.224), flexibility in adapting to changes (0.196), cooperation with respect to the degree of elasticity (0.137), sound financial circumstances (0.109), and cooperation with the executive director (0.087).
- (6). Finally, regarding the evaluation criterion, physical equipment and delivery services offered by the logistics center were assigned higher priority by the high-tech sector (0.667) compared with own motorcade (0.333).

Step 2.6: Selecting the most appropriate logistics company in terms of tax exemption
According to Table 4, the dominant values for three alternatives were calculated, as shown in Equation (6):

$$L = \begin{bmatrix} 0.420 & 0.442 & 0.328 & 0.457 & 0.444 & 0.392 \\ 0.358 & 0.348 & 0.425 & 0.327 & 0.352 & 0.399 \\ 0.223 & 0.211 & 0.248 & 0.216 & 0.204 & 0.209 \end{bmatrix} \begin{bmatrix} 0.156 \\ 0.200 \\ 0.178 \\ 0.165 \\ 0.154 \\ 0.147 \end{bmatrix} = \begin{bmatrix} 0.4137 \\ 0.3679 \\ 0.2189 \end{bmatrix} \quad (6)$$

The experts from the high-tech industry used the aforementioned standards to conduct integrity assessments for each candidate logistics company with a tax-exempt status. Finally, the alternatives were prioritized, and the highest score was assigned to the most appropriate logistics company. The logistics companies could be ordered as follows according to their assigned scores: logistics company A (0.4137), logistics company B (0.3679), and logistics company C (0.2189). These findings indicate that logistics company A was the most appropriate for the high-tech industry. The results are summarized in Table 5.

Table 5. Application of the AHP decision model within the high-tech sector to select an appropriate logistics company with tax exemption status.

Criteria	Weights of Overall Levels	Weights for Level 4		
		Logistics Company A	Logistics Company B	Logistics Company C
		Weight	Weight	Weight
Cost	0.156	0.420	0.358	0.223
Time	0.200	0.442	0.348	0.211
Quality	0.178	0.328	0.425	0.248
Management	0.165	0.457	0.327	0.216
Technology	0.154	0.444	0.352	0.204
Physical Equipment	0.147	0.392	0.399	0.209
Result	Aggregate Score Rank	0.4137 1	0.3679 2	0.2189 3

5. Discussion

This study integrated qualitative and quantitative methods into an outsourcing model to determine the most suitable logistics company. The modified Delphi method was adopted to reach a consensus among high-tech sector administrators and establish essential criteria for selecting the most appropriate logistics company with a tax-exempt status. The group consensus formed through the questionnaire survey was used to propose the most appropriate evaluation criteria and derive criterion weight values for suppliers. Next, the experts negotiated with each other. In addition, a private practitioner provided personal opinions through a resubmitted questionnaire until a general consensus was reached.

In the selection process, a high-tech company that must outsource its logistics should highly prioritize the viability of the candidate logistics company. A newly established logistics company with at least 3 years of operating experience in the logistics market was considered to have sufficient expertise. However, even a logistics company that temporarily suspends its operations, regardless of its serviceability, may bring potentially huge losses to the high-tech industry.

In this study, three logistics service suppliers were selected on the basis of their operational years in the high-tech field. A logistics company must be in operation for at least 3 years before it can be considered. According to the highest score, a logistics company with tax-exempt status was selected as an outsourcing partner. The AHP model was adopted in the high-tech sector to select the most appropriate logistics company with tax-exempt status. In addition, the AHP model can objectively and systematically assist high-tech managers in completing similar multicriteria tasks when selecting the most appropriate logistics company.

6. Conclusions

While preventing and controlling the spread of the COVID-19 pandemic, Taiwan has mastered technologies related to global semiconductor products, high-performance computing chips, 5G, AI, and other technologies; thus, the Hsinchu Science Park can continually record new highs in turnover. However, finding a suitable logistics company is necessary to handle a large amount of land, sea, and air logistics and ensure that products are delivered to customers on time. Choosing a logistics company for outsourcing is complicated and often subjective. Managers in high-tech industries often lack clear and objective decision-making procedures and evaluation criteria. In addition, most decision-makers mainly depend on the experience of candidate logistics companies to obtain tax-exempt status. Accordingly, this study proposes a two-stage evaluation model for determining the most suitable logistics companies for outsourcing. The model can provide decision-making and evaluation criteria for high-tech managers, and such criteria can enable the logistics sector to outsource to logistics technology contractors. In terms of establishing criteria and weights, the integration of the group decision-making process and the modified Delphi method can help Taiwan's high-tech industry build consensus among logistics experts. The results reveal that managers in the high-tech sector prioritized the compatibility of the service time and the quality of the logistics company, followed by the cost, technical capabilities, and management of the candidate logistics company. Physical equipment had the lowest priority. In addition, high-tech sector administrators can consider individual demands to add to the criteria or evaluate actual data packaging in the AHP model.

7. Limitations and Future Research Directions

This study used only the AHP. In the future, this method can be combined with other research methods, such as SAW, TOPSIS, and fuzzy, to calculate weights [63,64]. In addition, studies can compare whether rankings calculated by these research methods are the same as those calculated using only the AHP.

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