Greener Journal of Environment Management and Public Safety
ISSN: 2354-2276
Vol. 13(1), pp. 99-107, 2025

https://gjournals.org/GJEMPS
DOI: https://doi.org/10.15580/gjemps.2025.1.032725056

Supplier Selection Using Analytic Hierarchy Process Approach: A case study in the retail toy company.

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ABSTRACT

Supplier selection is one of the most vital functions of a retail supply chain. Every demand should match a supply. By deciding the best supplier to fulfil a demand, retail companies can save material and service costs and optimize profits. However, this decision becomes complex for business managers because of multiple suppliers, criteria, and parameters. On the contrary, having only one supplier to satisfy multiple demands may also rapture the supply chain and lead to uncertainty and profit loss. Thus, to increase the company's profits, multi-criteria decision-making tools are used for supplier selection problems. One of these decision-making tools is the Analytic Hierarchy Process (AHP) approach. Previous research has been done for supplier selection using AHP in various industries. This case study aims to propose a decision model for supplier selection using the AHP approach which is later applied to a retail toy company. The objective is to optimize company profit. Through this approach, an optimization could be made for further supply selectors. Based on AHP approach's result, it is shown that one out of three alternative suppliers have fulfilled the criteria that can give the highest profit for a small-medium enterprise (MSE) retail toy company.

ARTICLE'S INFO

***Article No.:* 032725056**
***Type*: Research**
***Full Text:* PDF, PHP, MP3**
***DOI:* 10.15580/gjemps.2025.1.032725056**

Accepted: *02/04/2025*
Published: *30/07/2025*

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Keywords: *Supplier Selection, Analytic Hierarchy Process Approach, retail supply chain, company profit, toy company*

1. INTRODUCTION

A retail supply chain comprises sets of locations and processes that stakeholders use to ensure that products reach the consumers, from raw materials to production to finished goods delivery at the customer's doorstep. In the past, retailers acted as passive recipients of allocated goods from manufacturers in anticipation of demand. Today, they actively design and direct product supply to fulfill customer demand by controlling, organizing, and managing the supply chain from production to consumption [1]. In other words, retailing is concerned with product availability. Retailers are an important link between manufacturers, wholesalers, and customers. One of the critical roles of retailers is to add value to products and services sold to customers. It is often difficult to perfectly always match supply versus demand, while being in the middle of supply and demand. If there is too much product versus demand, the price must be marked down, and the company incurs high storage costs. If it is too little, the company incurs the opportunity cost from lost sales and customer disappointment [2].

Thus, optimization for any retail business and research relating to profit maximization has been made. Some research tends to maximize the profit exceeding targets [3], some correlate to inventory [4] and demand [5], other research has correlated this maximization to transportation and logistics costs of the goods [6] from supplier to warehouse [7], and lastly, profit maximization was also applied to inventory management [8]. On the other hand, supplier selection is also part of profit maximization [9]. Since the cost was established as an integral part of profit maximization, supplier selection based on location is crucial. The farther away the supplier is from the warehouse or retail, the higher the cost it would take to transport the goods. Fortunately, optimization tools on supplier selection are available to be used by supply chain practitioners to obtain optimal profits. This project, however, focuses on the use of the Analytic Hierarchy Process (AHP) for the supplier selection decision model.

This paper is organized as follows: Section 2 enlightens how the AHP approach benefited various industries and companies in the decision-making process. Section 3 elaborates the problem and objectives of the case study using numerical values and formulas. Section 4 shows optimization results using the AHP approach and recommendations. Lastly, Section 5 explains the study's supplier selection conclusion and future research direction.

2. LITERATURE REVIEW

The supplier selection process refers to analyzing and measuring the performance of various suppliers. Like any other selection process, it involves ranking and selecting to meet its competitiveness. Various values and attitudes are involved in the selection process that is often conflicting and complementary. Thus, all these factors, criteria, and parameters should be considered in the analysis. A well-known Analytical Hierarchical Process to evaluate complicated decision problems was developed by Saaty (1980 and 1994). Analytical Hierarchy Process (AHP) is the most utilized multi-criteria methodology [10]. It is a theory of measurements that provides the ability to integrate both qualitative and quantitative factors in the decision-making process by organizing perceptions, values, feelings, judgments, memories, past experiences, and performances into a multi-level pyramidlike structure that weights the forces that influence a decision [11].

The research was done using the AHP approach for a vendor selection of a telecommunication system, compared to the pre-existing selection process. With five criteria and 26 sub-criteria, priority weights were complex but evaluated. This result also reveals that the pre-existing selection and the AHP approach can develop the same successful decision. However, using the pre-existing process took five months to complete. This shows that AHP can significantly reduce the time and effort in decision- making [12].

Another application of AHP was conducted to evaluate convention site selection. With a three-level hierarchy, five criteria, and 18 sub-criteria, the researchers discovered that accommodation facilities and site environment dominate importance in convention site selection [13].

Surprisingly, another research study was made by students for choosing the best school in college. Applying the mathematical model of AHP based on qualitative criteria, students have designed a decision model for selecting technical or engineering schools [14].

Other research uses selection models and the AHP approach to facilitate complex decision-making for diverse industries like hospitals [15], steel manufacturing [16], project renewal energy resources [17], and the retail industry [18]. Research shows that complex decision criteria of any company or industry can be analyzed using mathematical models. In addition, the supplier selection hierarchy model developed advanced technology by FTS Chan and HK Chan of the University of Hong Kong [19] were comprehensive and foundational. The six (6) hierarchy selection criteria include tangible and intangible attributes, namely: cost (information, competitive pricing, and total cost), delivery (distance, reliability, dependability, and delivery speed), flexibility (product mix, modification, and volume), innovation (product innovation, technological capabilities, and sharing), quality (conformance to specification, product durability, and product reliability), and customer service (handling of complaints, information sharing, and problem-solving aids).

A few relevant supplier selection criteria mentioned above for this case study are included in the Analytic Hierarchy Process (AHP) model formulation. The subsequent paragraphs describe the measurement of criteria based on the importance of each dimension, such as suppliers' reliability or ability and willingness to handle demand changes.

3. PROBLEM DEFINITION AND FORMULATION

A. Problem Statement

This study aims to propose a decision model for the supplier selection process, which becomes the case problem for the company to select the best supplier to fulfill customer demand. The objective is to optimize company profit.

B. Solution Method

The solution methodology adopted for this study consists of formulating the supplier selection criteria model using the Analytic Hierarchy Process (AHP) approach. To facilitate numerical computation, the researchers explored the use of Super Decision [20], a decision-making software that accommodates optimization problems with multiple criteria.

C. Data Collection

The researchers selected a small-medium enterprise (MSE) retail company to propose a practical application of an optimized supplier selection model. The company data used in this case study are real numbers, but other details are kept confidential, like product details, suppliers' names, locations, addresses, and sales period. The numerical representations were voluntarily provided and disclosed to the researchers by the company owner. The research is focused on the retail toy store that offers various product line items, fulfills the demands of several customers, and handles multiple suppliers. Precisely for this case study, the problem covers five (5) product line items of model toy kits, sourced from three (3) suppliers based locally and internationally, as shown in Table 1 below:

Table 1. Product vs Supplier Alternatives

Model Kits	Supplier
1. SD Kits	1. Japan 2. Laguna 3. Quezon City
2. HG Kits	
3. RG Kits	
4. MG Kits	
5. PG Kits	

D. Supplier Selection Criteria

Identifying supplier selection criteria is essential in the model formulation process. Out of the six (6) hierarchy selection criteria listed by FTS Chan and HK Chan [19], four (4) competitive measures are used in this study. Due to the smaller-scale business setup, no sub-criteria were defined. Description of the selection criteria is shown in Table 2 below:

Table 2. Selection Criteria

Definition Criteria	**Definition [19]**
1. Cost/Income	It is measured based on the importance of the cost/price dimensions: total cost, the supplier's willingness, and ability to share: cost data, and the unit price
2. Delivery Leadtime	It is measured based on the ability and willingness to expedite an order, how quickly it can deliver, the ability of a supplier to meet due dates, and supplier location.
3. Payment Scheme	It is measured based on the supplier's attitude to handle payment arrangements and the ability and willingness to provide problem solving aids.
4. Stock Variety	It is measured based on the importance of flexibility, the ability and willingness to change order volumes and to change the mix.

E. Building the EHP Model

The AHP model for the case study is developed using three (3) alternatives that are evaluated in terms of four criteria (the second level of hierarchy).

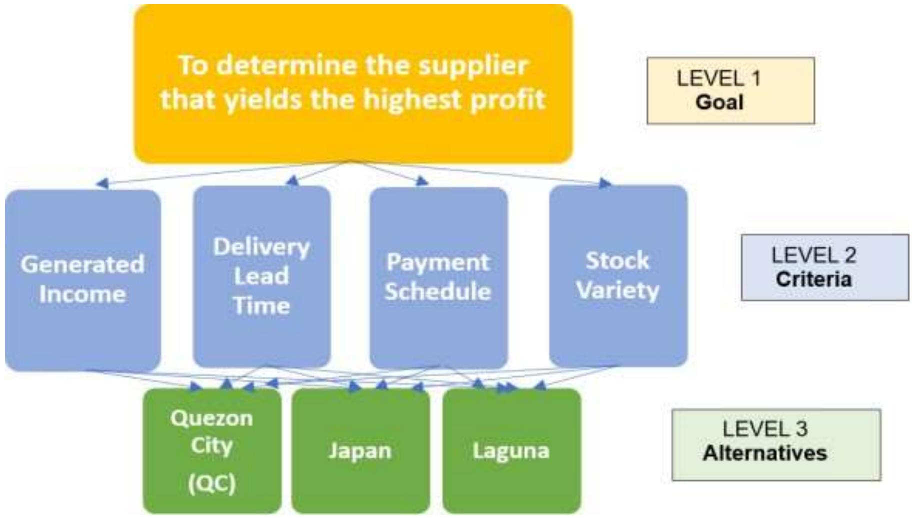

Fig 1. The AHP Diagram Using Super Decisions

Figure 1 above displays the AHP model generated by using Super Decisions software. The application shows panels of the parent node (refer to level 1) and children node (refer to level 2) inside the inner part of the panel. The program begins with the goal node, which then systematically goes down to the criteria node. These elements are individually connected to the elements of the alternative node for the subsequent pairwise rating comparison. The AHP model in Super Decisions table is shown in Appendix A-1.

F. Judgement Scales

The built-in pairwise comparison feature of Super Decisions is used to rate the criteria's importance and the alternatives' preference. The input values are encoded by using the management's suppler pre-evaluation ratings and the Saaty Rating Scale, as shown in Table 3 below:

Table 3. Saaty Rating Scale

The Intensity of Importance/Preference	Value
1	Equal importance
3	Somewhat more important
5	Much more important
7	Very much important
9	Absolutely more important
2,4,6,8	Intermediate values

The importance of the criteria is assessed using the questionnaire rating format under the Judgments tab as shown in Appendix A-2. On the other hand, the intensity used to rank the criteria is based on the value indicated by the management's initial evaluation of the suppliers. The computation and analysis of the problem using Super Decisions software are discussed in the subsequent paragraphs.

4. COMPUTATIONAL RESULT AND ANALYSIS

In Super Decisions, the consistency of the ratings is checked to ensure the reliability and accuracy of the analysis. As a rule of thumb, the inconsistency index must be less than or equal to 0.1 [21]. As depicted in Figure 2 below, the inconsistency index obtained from the comparison of generated income and delivery lead time is 0.02969, which meets the abovementioned requirement.

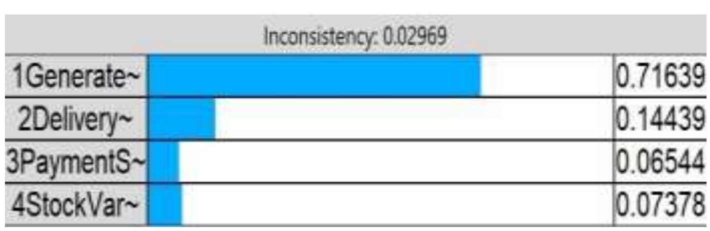

Fig 2. Consistency checks for the criteria when generated income and delivery time are compared

Referring to the exact values of the generated incomes of each supplier, as shown in Table 4 below, values are directly entered into the software to rate the alternatives in terms of the generated income criterion.

Table 4. Generated Income of Each Supplier

Supplier	Generated Income (PHP)
Quezon City	39,939
Japan	16,740
Laguna	12,814

Note, however, the values used in the software represent the rounded-up figures of the generated incomes (nearest ten thousand) to avoid introducing unnecessary complexity to the analysis. Like the pairwise rating comparison of the criteria, the questionnaire is used to rate the alternatives in terms of delivery lead time, payment schedule, and stock variety. On the other hand, the degree of preference is the deciding factor instead of rating the suppliers by importance. Appendix A-3 shows the comparison and consistency check for the Japan and Quezon City suppliers regarding delivery lead time.

To verify that no incomplete comparisons and no duplicated goals are specified, the Sanity Check feature of Super Decisions is run to confirm the completeness and accuracy of all data. The comparisons of the alternatives, criteria, and the corresponding consistency checks are provided in Appendix (A-4 through A-8).

Based on the synthesized values presented in Appendix A9, the suppliers' priorities are summarized in Table 5 below. The mathematical computation using the Super Decision application software shows that the Quezon City supplier is the ideal choice, followed by Japan and Laguna suppliers.

Table 5. Results of AHP Modeling Using Super Decision

Supplier	Priority
Quezon City	1.000000
Japan	0.700105
Laguna	0.352513

The results presented in Table 5 above suggest that the company can achieve the highest profit by selecting Quezon City suppliers first, then Japan, and Laguna. Based on the AHP model developed and Super Decisions computational result, the researcher team recommends the business owner to purchase goods from Quezon City supplier to obtain maximum profit gain (case objective).

5. CONCLUSION AND FUTURE RESEARCH

Retail companies manage suppliers to achieve maximum profit in the supply chain. Business owners deal with multiple suppliers, making the selection process a complex decision-making activity. The supply management task is critical as it requires criteria analysis of goods and services to match customer demand. Thus, in this case study, the researchers explored the well- known Analytical Hierarchical Process (AHP), which prioritizes, analyzes, measures, and weights suppliers' performances based on qualitative and quantitative factors.

The selection model developed in this study is limited to a small-scale retail store business. Only five of the several product lines were evaluated against three suppliers and four selection criteria. Hence, case results cannot be generalized to other more prominent companies. Nevertheless, the AHP approach and Super Decisions software tools used in this research apply to different business sectors. The framework model can be modified into a larger structure to solve complex supplier selection problems.

Despite its limitations, this study provides significant results and a foundation for future research efforts. In this case study, the evaluation team selected the Quezon City supplier as the best supplier to optimize company profit based on the following selection criteria: cost/income, payment, delivery, and stock variety. The implementation of the proposed Selection Model is beyond the scope of this paper. Thus, actual business gain and profit increase are not reported. In future studies, researchers can utilize other optimization techniques, such as focusing on profit maximization or cost minimization, to determine the best supplier. Researchers can modify the hierarchy model by adding more strategic priorities, supplier criteria and sub-criteria, and weightings relevant to the business. In addition, a Sensitivity analysis can also be used. This analysis can discuss the impact of the changes in values of the Selection Model when the business owners change the priorities based on fluctuating actual market situations.

ACKNOWLEDGMENT

The researchers would like to thank the retail merchandise company G-16 Base Hobby Store, and the Mapua University Graduate School for supporting this study.

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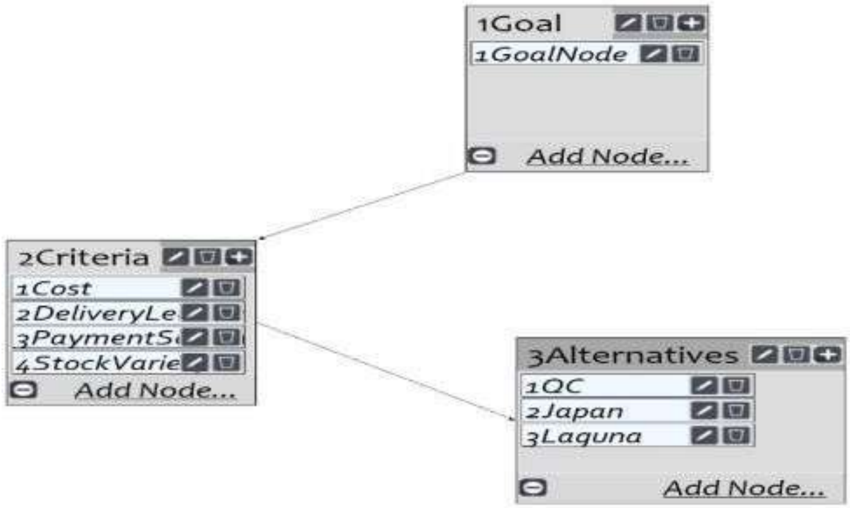
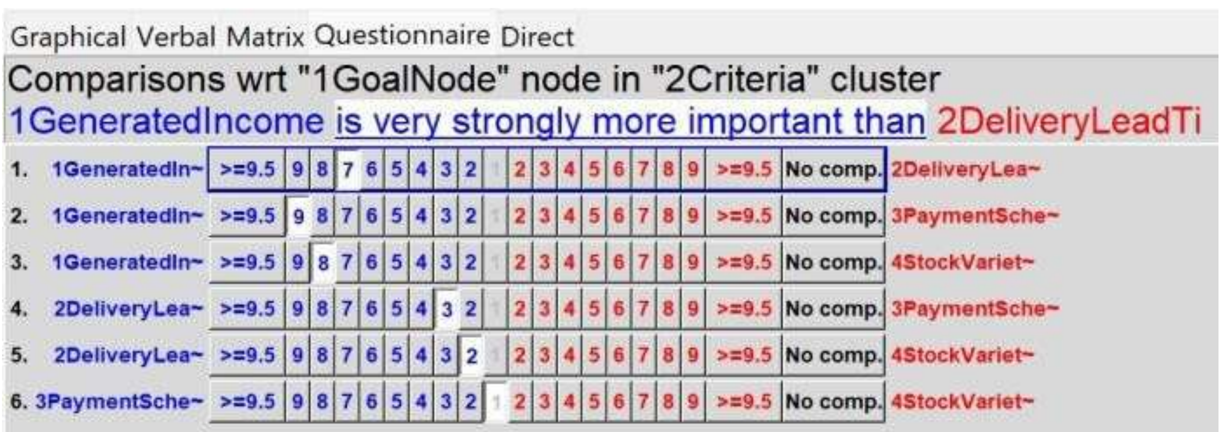
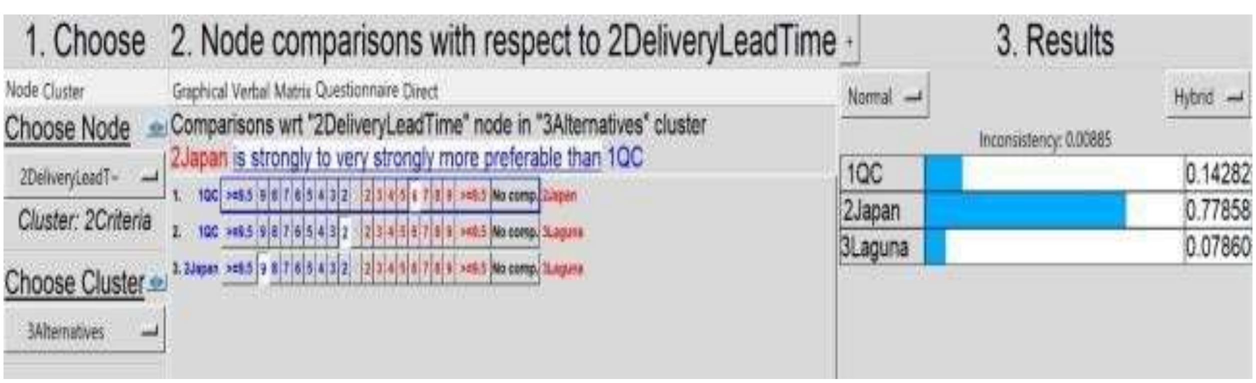
Appendix A



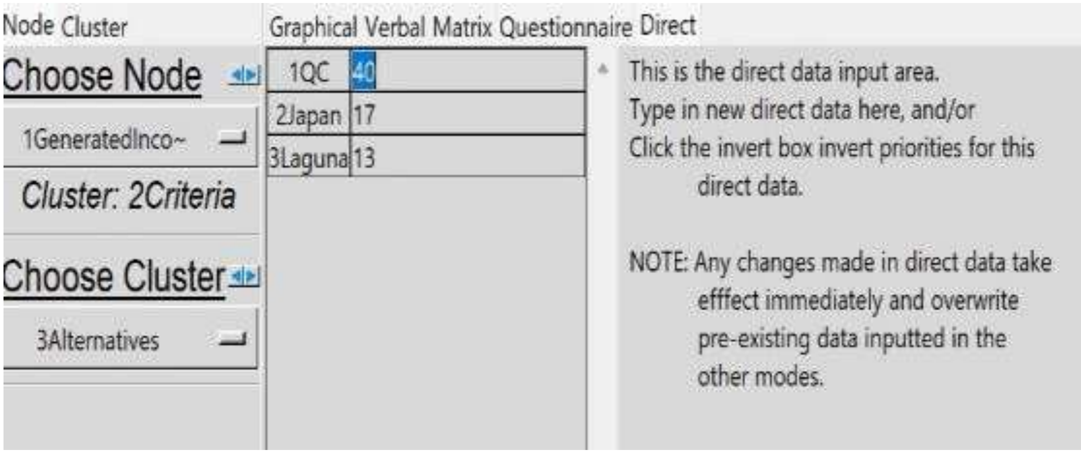
Appendix A-1: The AHP model using Super Decisions



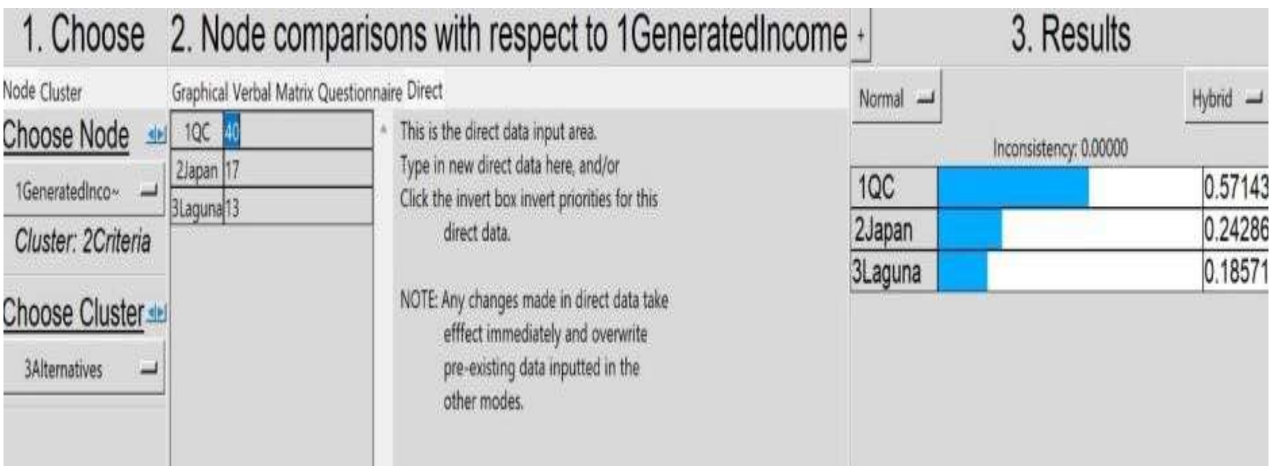
Appendix A-2: Comparison of the importance of income and delivery lead time. The two criteria are rated straightforwardly by using absolute numbers. For item no. 1, the value "7" indicates that the dominant element (i.e., criteria written in blue, which is the generated income in this case) is seven times more important than the other element (i.e., delivery lead time).



Appendix A-3 Comparison of the Japan and Quezon City suppliers in terms of delivery lead time

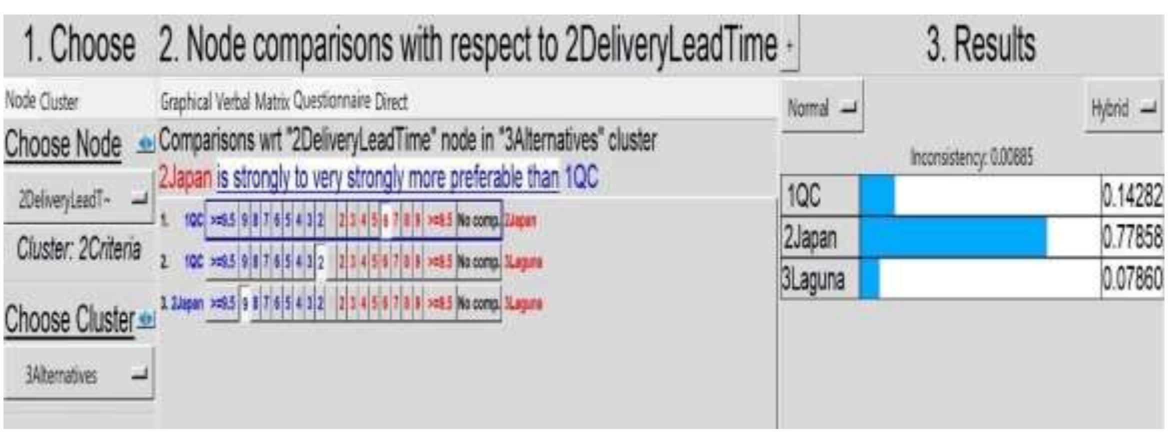


Appendix A-4 Rating the alternatives based on income

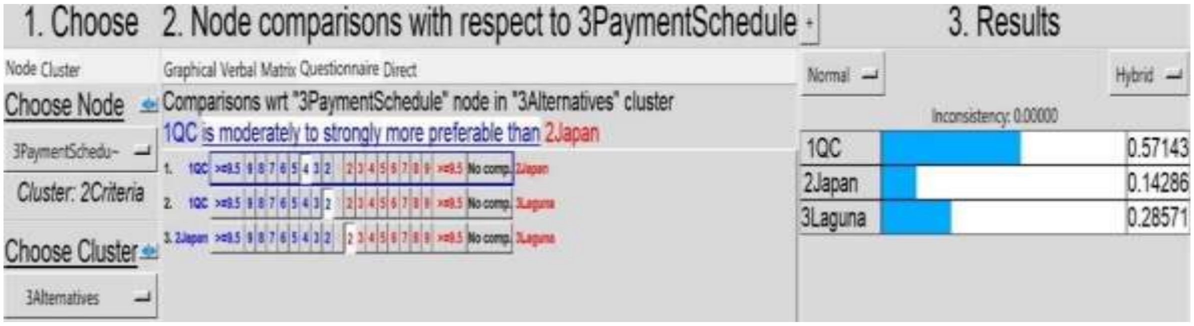


Appendix A-5 Rating of alternatives based on cost/generated income.

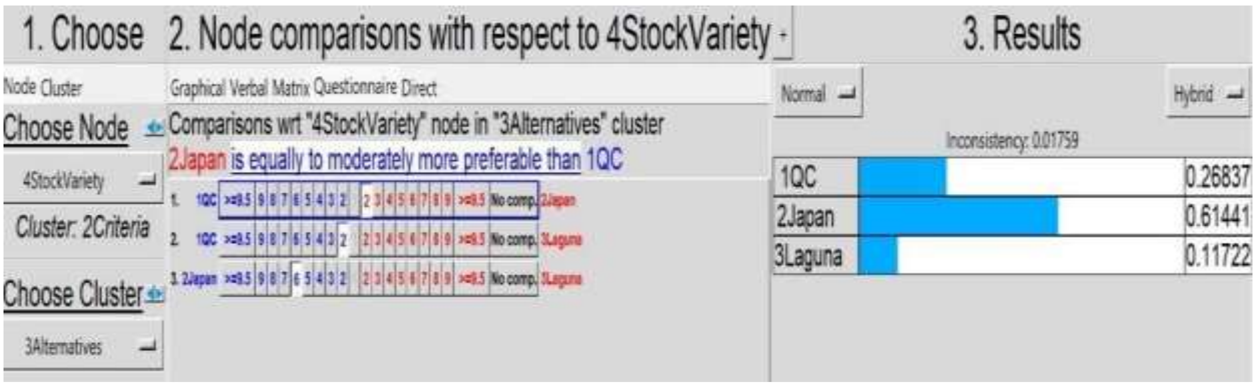
Note: The input values are rounded values from the table presented in the formulation of the objective function, in thousands [i.e., QC-40,000, Japan-17,000, Laguna-13,000]



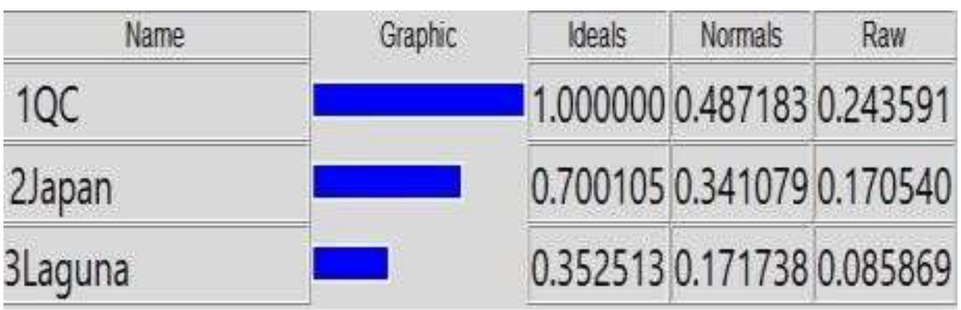
Appendix A-6: Rating of alternatives based on delivery lead time



Appendix A-7: Rating of alternatives based on the payment schedule



Appendix A-8: Rating of alternatives based on a stock variety



Name	Graphic	Ideals	Normals	Raw
1QC		1.000000	0.487183	0.243591
2Japan		0.700105	0.341079	0.170540
3Laguna		0.352513	0.171738	0.085869

Appendix A-9: Synthesized values of the evaluated suppliers

Cite this Article: Villanueva, JI; Paras, AR; Estrella, V; Aulia Henock Pandu Putra, AHP; Ho, H; Redi, AANP (2025). Supplier Selection Using Analytic Hierarchy Process Approach: A case study in the retail toy company. *Greener Journal of Environmental Management and Public Safety*, 13(1): 99-107, **https://doi.org/10.15580/gjemps.2025.1.032725056**.