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Analytical Hierarchy Process for Enhancing Procurement Decision-Making in Project Phase: A Case Study in the Gold Mining Project

Budi Irawan Saleh[1]*, Choirul Anwar[2], Rusman Zaenal Abidin[3], and Aris Setyo Radyawanto[4]

[1-4]Master of Industrial Engineering Program, Mercu Buana University
Jln. Meruya Selatan No.1, Jakarta Barat 11650, Indonesia
[1]Irawan_saleh@yahoo.co.id; [2]choirulanwarst@gmail.com;
[3]rusman.abidin@gmail.com; [4]aris.radyawanto@gmail.com

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Abstract **-** The aim of the research was to enhance the selection for the process plant equipment supplier based on their country of origin in the gold mining project using the Analytical Hierarchy Process (AHP). The research also intended to investigate how AHP could further enhance the process of the project. The steps for modeling the AHP were identifying the hierarchy by the project team, constructing the AHP model, and calculating the weight for supplier selection. The research object was a gold mining company based in Indonesia. The schedule and resources were calculated, followed by a survey to evaluate the AHP process. After modeling and calculating using AHP, it is found that the three highest criteria for selecting the process plant equipment suppliers are running capacity (14,3 %), efficiency (9,9%), and endurance (9,7%). The overall scores for each supplier show that supplier from United States (25,87%) is in the first rank. It is followed by Germany (25,80%) and Australia (25,20%). Moreover, AHP is proven to enhance the process by not only reducing the time of decision-making for two days but also increasing the resource by almost 23%. Based on the survey to the project team, AHP increases the involvement of the project team in the decision-making process and shows that more than 80% of the project team agrees with the decision. The survey also reveals that almost 63% of the project team decides to use the same tools for the decision-making process.

Keywords: Analytical Hierarchy Process (AHP), procurement decision-making, gold mining project

I. INTRODUCTION

During the past years, gold mining industries in the world have become an exciting industry because of an increase in the gold price and its high return through the years. However, it is among the highest capital industries due to the high risk and high cost of investment. The gold mining industry has flourished in many developing countries with great resources and created massive capital investment due to its remote locations and low infrastructure areas. Indonesia is one of the developing countries that have also been affected by this phenomenon that the gold mining industries have grown increasingly in numbers (Singawinata, 2007).

The gold mining industry is divided into two standard processes for gold extraction. Meanwhile, the principle has not yet changed in decades. The first process of gold extraction is by using the smelter, and the second one is by leaching. The leaching process becomes a typical process in the industry due to low-cost investment and being straightforward methods. Carbon in Leach (CIL) is one of the popular means in the leaching method. Now, the technology has been revolved to get the most of the gold with higher return (Stange, 1999). CIL is working in principle with the simultaneous leach and absorption process. The technology provider for this process is available only for a small number group of companies. These companies are based and characterized by their respective countries that are usually involved in the mining process in a decade such as United States, Germany, Australia, and South Africa. In the

*Corresponding Author

present, emerging countries such as China and India have started to provide this technology. However, Indonesia, as a gold producer, has yet emerged as a technology provider for this process, and it needs other technological provider countries for gold processing plants (Singawinata, 2007).

Selecting the suppliers with a variety of criteria will make the process even more difficult. The requirements should be right because it will impact the other phase of the project, which is construction and operation. This process requires also spend an amount of time and be the most critical activity in the project that needs to be done correctly (Min, 1994). A typical method of decision-making in the project is conducted by using meetings and discussions among the project team. Then, the decision will be based on the consensus from the senior management and project owner. This process will require experience and knowledge of the senior management and long durations within one session to another. There are consequences of a lack of support for the final decision from the project team that is not involved in the decision-making process.

Selecting the supplier or technology provider for a gold processing plant from a global supplier requires a delicate process. Haq and Kannan (2006) explained some of the attributes to select the international-based supplier. The main criteria were divided by finance, quality, risks, service performance, partnership, cultural and communications, as well as trade restriction. Similarly, Kahraman, Cebeci, and Ulukan (2003) considered suppliers based on supplier criteria, product performance criteria, and service performance criteria. To select and assess the supplier for this process plant equipment, some of these criteria need to be evaluated.

The Analytical Hierarchy Process (AHP) is the most common method for selecting suppliers in a multi-attribute approach. It was first developed by Saaty in 1980 to determine the importance of set activities in a multi-criteria problem. It is one of the Multi-Criteria Decision-Making (MCDM) techniques, based on the three principles. Those are the model structure, a comparative structure and quantification for the criteria and alternative, as well as creating and selecting the priorities (Luzon & El-Sayegh, 2016).

The first process in AHP is to develop the hierarchy. In developing the hierarchy, the objective needs to be defined and decomposed. The decomposition process needs to be adjusted to the level of detail (Bali & Amin, 2017). To get higher accuracy, it requires a full decomposition until it reaches the end. Some levels are developed from the goal to criterion and alternatives, as seen in Figure 1. The second phase is to set up priority or judgment. Prioritization is done at every level of the hierarchy. A pairwise judgment matrix is constructed by element and element and compared to their next level using the nine-point rating that has been developed by Saaty in Table 1 (Pieter, Lamia, & Wattimena, 2017; Pjevcevic, Dimitrijevic, Bisevac, & Vukadinovic, 2018).

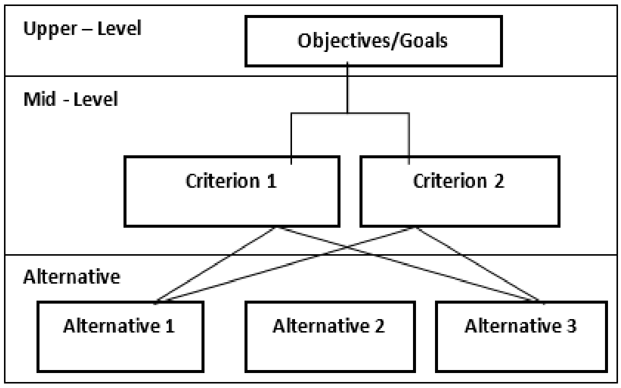

Figure 1 A Standard Hierarchical Structure Sample for AHP

(Source: Luzon & El-Sayegh, 2016)

Table 1 Saaty's Rating Scale

No	Definition	Explanation
1	Equally important	Two factors contribute equally to the objective
3	Somewhat more important	Experience and judgment slightly favor one over others
5	Much more important	Experience and judgment strongly favor one over others
7	Very much more important	Experience and judgment very favor one over others
9	Absolutely more important	Experience and absolutely favor one over others
2-4-6-8	Intermediate values	When compromise is needed

(Source: Pieter *et al*., 2017)

Haq and Kannan (2006) used the Fuzzy and AHP models to evaluate and select vendors in the supply chain. Moreover, Rajesh and Malliga (2013) combined QFD and AHP for supplier selection methods. Then, the other researchers such as Ahmadi and Azadani (2018); Luzon and El-Sayegh (2016); Fu (2019); Jain, Sangaiah, Sakhuja, Thoduka, and Aggarwal (2018); Nallusamy, Sri Lakshmana Kumar, Balakannan, and Chakraborty (2016); Deng, Hu, Deng, and Mahadevan (2014); Khalil, Kamaruzzaman, and Baharum (2016); Deepika and Kannan (2016); Das and Saha (2016); Luthra, Govindan, Kannan, Mangla, and Garg (2017); Mathiyazhagan, Diabat, Al-Refaie, and Xu (2015); Santoso and Besral (2018); Polat and Eray (2015); UmaDevi, Elango, and Rajesh (2012); and Jayant (2018) have used AHP as tools and methods for supplier selection in a different aspect area. All results show that AHP has given a great result in supplier selection.

Based on the literature review, the objective of the research is to assess and select the supplier for process plant equipment and to prove that the MCDM

(AHP) method can enhance the schedule of decision making in the projects. The research also investigates the advantages and disadvantages of using the method in the real project situation.

II. METHODS

The research object is a gold mining company based in Indonesia. Indonesia which is chosen because it has much supplier variety in its their respective country and will be used as guidance for procuring the equipment. The product is only for gold processing equipment plants based on CIL processing methods, which consists of all main equipment excluding the Balance of the Plant (BOP) and other infrastructure (offices, workshops, roads, electrical substations, and others). The research was conducted in the early phase of the project in December 2019. Then, the selected country of suppliers for the process plant equipment is from South Africa, Australia, United States, Germany, and China.

The process starts by identifying the hierarchy (main criteria and subcriteria). The senior project team begins by holding a project meeting with the project owner. This meeting is to seek the main criteria and subcriteria to choose a supplier for the process plant equipment. The meeting is attended by the project owner, Project Manager, Senior Contract Engineer, Senior Procurement Engineer, Engineering Manager, Finance and Cost Manager, Project Control Manager, Technical Advisor, and Process Manager. They are at senior-level with a minimum of 18 years of experience in the gold mining process plants. They brainstorm to decide the main criteria. Each of the senior project team holds responsible for each main criteria. Then, they will meet with their respective team for decomposing the subcriteria.

AHP model is constructed based on the final consensus in the project meeting. The first hierarchy is the project goal, which is supplier selection. The second hierarchy or main criteria is based on the criteria which have been agreed upon by the senior project team. The third hierarchy or the subcriteria is also set in consensus inside the project meeting. Moreover, the relative weight is calculated by the right eigenvector (w) corresponding to the largest eigenvalue (λmax) using Equation (1) as follows:

$$A_w = \lambda_{max} w \tag{1}$$

The matrix is consistent if matrix A has the first rank and λ_max=n. Normalizing rows or columns in A can obtain the weights. Then, to measure Consistency Index (CI) as a deviation or degree of consistency, the researchers use the following Equation (2):

$$CI = (\lambda_{max} - n)/\,(n-1) \tag{2}$$

Then, the final Consistency Ratio (CR) is calculated to see whether the evaluation is sufficiently consistent or not. The calculation is based on Equation (3):

$$CR = \frac{\mathrm{CI}}{RI} \tag{3}$$

Next, Random Index (RI) in Table 2 is measured. If the Consistency Ratio (CR) is ≤ 0,1, the inconsistency is acceptable. However, if the CR is ≥ 10%, the process is repeated to improve the CR (Pieter *et al.*, 2017).

Table 2 The RI coefficient

Size of Matrix	RI
1	0,00
2	0,00
3	0,58
4	0,90
5	1,12
6	1,24
7	1,32
8	1,41
9	1,45

(Source: Pieter *et al.*, 2018)

For the main criteria, the measurement for the pairwise comparison matrix is decided by consensus in meeting by the senior team and project owner. The subcriteria is chosen in agreement by each of the responsible senior team and their teams. The supplier is selected based on the calculation from Tam and Tummala (2001) and Liberatore, Nydick, and Sanchez (1992). It calculates the global weight and the scale based on with a five-point scale: Outstanding (O), Good (G), Average (A), Fair (F), and Poor (P). The last level of the hierarchy consists of alternatives. The five potential suppliers for process plant equipment are from South Africa, Australia, the United States, Germany, and China.

Next, a comparison of schedule and resource between using AHP and standard project decision-making is analyzed. The survey is conducted for all project teams based on the Likert scale (Joshi, Kale, Chandel, & Pal, 2015). The questions are asked with an option. Those are the final decision for the supplier selection (very dissatisfied, dissatisfied, neutral, satisfied, and very satisfied) and usage of the same tools for another critical decision-making in the project (strongly disagree, disagree, neutral, agree, and strongly agree).

III. RESULTS AND DISCUSSIONS

Based on the first project meeting, the senior project team and project owner has decided to create seven aspects of the main criteria. It includes finance, schedule, quality, operation, service, business consideration, as well as health and safety. Then, the respective senior team brainstorms with their team to list out the subcriteria based on their responsibilities. Senior Contract Engineer is responsible for business consideration aspects. Then, Senior Procurement Engineer is in charge of service aspects. The Engineering Manager is accountable for quality. Meanwhile, Finance and Cost Manager has a responsibility in the financial aspect. Next, Project Control Manager is responsible for the schedule aspect. Not only Technical Advisor and Process Engineers are in charge of health and safety, but they also advise the team. The decomposing result from the main criteria shown in Table 3 (see Appendices). Then, the full hierarchy diagram showing the goal, main criteria, and subcriteria is shown in Figure 2 (see Appendices).

A pairwise comparison matrix is based on the main criteria with the nine-point rating. The input is decided by the consensus between the senior project team and project owner meeting. The matrix can be seen in Table 4 (see Appendices).

Then, the matrix is normalized. It calculates the priority factor (weight) as seen in Table 5 (see Appendices). The CR is calculated and resulted in 0,08, which is less than 0.10. It means that the values are consistent. From the normalized weight, it reveals that the ranks in the main criteria, those are ((1) operation, (2) health and safety, (3) quality, (4) financial aspect, (5) schedule, (6) service, and (7) business consideration). The main criteria from consensus from the respective senior team show that the financial aspect is not the top priority. However, the main priority lies in operation and quality. The results are illustrated in Figure 3 (see Appendices).

Furthermore, the subcriteria pairwise comparison matrix is inputted and normalized. The priority factor (weight) is calculated. Then, the CR is calculated to know the consistency. It is observed for each matrix that CR is less than 0,01. Thus, the inconsistency is acceptable. The results of calculation can be seen in Table 6 (see Appendices). There is no CR value in each subcriteria that exceed 0,01 (10%). Moreover, it is in the range from 0,06 (6%) to 0,09 (9%).

Next, the weights are extracted from their respective priority factors. Then, the global weight for each subcriteria is calculated by multiplying the local weight from subcriteria and local weight from the main criteria. In Table 7 (see Appendices), the top five subcriteria based on their global weight are running capacity, efficiency, high endurance, health and safety compliance, an as well as sustainability. Meanwhile, the three lowest subcriteria are communication, commissioning service, and forex rate. The higher the weight is, the higher the influence is for the next calculation.

Next, the subcriteria are ranked from the highest to lowest weight based on their global weight. In Table 8 (see Appendices), the first rank is from the operational side. It is the running capacity of the process plant equipment. It has the highest weight due to the process of plant equipment to achieve the running capacity for production effectiveness. The lowest subcriteria is contract and agreement. It is reasonable because the contract and agreement can be adjusted based on the understanding of both parties.

To select the supplier of process plant equipment, the rating scale is used to evaluate the ranks. It is based on the criteria of Outstanding (O), Good (G), Average (A), Fair (F), and Poor (P). The pairwise matrix is developed for the criteria and normalized to see their respective weights. The weight is used to quantify the criteria as seen in Table 9 (see Appendices). The order follows the criteria which the heighest weight is Outstanding (O) and the lowest is Poor (P).

The weights from those criteria are multiplied with the global weights in each subcriteria to get the total score. As seen in Table 10 (see Appendices) and Figure 4 (see Appendices), the highest rank for the supplier is from the United States (25,87%). It is followed by Germany (25,80%). The suppliers from Germany and United States almost have the same rank. However, the United States supplier win in quality support, durability, and manufacturing duration. Therefore, it can be concluded that the senior project team can consider the supplier from United States. Meanwhile, the supplier from South Africa is the second-lowest due to the lowest score in the operation criteria (the highest weight), and the supplier from China has the lowest rank. In the quality aspect, the supplier from China has the lowest score among all of the suppliers.

Next, the schedule is analyzed for decision-making between using AHP methods and without using AHP methods in the projects. It can be seen in Figure 5 (see Appendices). It shows that the durations with AHP is shorter than without AHP. It can save for two days. It is because without using the AHP method takes longer to set up the criteria by discussion after meeting among themselves and the project team. Thus, the senior project team has a faster time to decide everything.

Moreover, the resource evaluation by hours is also investigated by using AHP and without using AHP. It is found that the decision-making by using the AHP method will require all project teams to participate in inputting the criteria. Thus, it results in higher total allocated hours compared to without using AHP. The senior project team only asks some of the subordinates, whom they feel, are required for discussion and creating criteria. The total differences are 96 hours. It equals a 23% increase in resources, as presented in Table 11 (see Appendices).

Last, the survey is conducted to evaluate the AHP process by the project team. The result is summarized in Table 12 (see Appendices). Almost 50% and 31% of the project teams strongly agree for the final decision with no disagreement. It shows that the final decision using AHP has a higher result in the approval of the project team. Similarly, the result also indicates that 63% of the project team agrees to use the AHP as tools in decision-making in other critical items.

IV. CONCLUSIONS

AHP is MCDM that can be used for selecting the supplier of process plant equipment in the gold mining project. The top three criteria for choosing the process plant equipment suppliers are running capacity (14,3 %), efficiency (9,9%), and endurance (9,7%). After inputting the weight for supplier selection, the supplier that in the first rank is from the United States (25,87%). It is followed by Germany (25,80%). The supplier from the United States wins in quality support, durability, and manufacturing duration. The supplier selection process reveals that price is not the most priority for supplier selection. Then, it implies that AHP can manage the priorities in the selection process.

After the evaluation of the schedule and resource of the AHP process, it shows that AHP can reduce the decision-making process for two days. However, the AHP process increases by 23% of the total hours. It indicates that AHP is an effective decision-making tool, but, in the project, it can burn out the resources and result in a higher cost than the normal process. Furthermore, in the survey conducted to evaluate the AHP process with the project team, the result reveals that almost 81% of the project team agrees with the final decision. It also shows that 63% of the project team decides to use the AHP process for other critical decision-making in the project. That result implies that the use of AHP will increase the involvement of the project team during the decision-making process. It also means the higher the acceptance from the project team is, the higher the confidence in choosing the right decision in the project will be.

There are several research limitations. First, the research is limited to the supplier selection for gold process plant equipment based on CIL processing methods for the Indonesian gold mining project. It consists of all main equipment, excluding the BOP and other infrastructure (offices, workshops, roads, electrical substations, and others). Second, the research was conducted in the early phase of the project in December 2019. Third, AHP models are conducted using manual input. Therefore, further research is still wide open. Future researchers can combine Fuzzy methods with AHP or use automation software (expert choice or web-based).

REFERENCES

Ahmadi, S. A., & Azadani, M. N. (2018). Solving the suppliers selection problem in the supply chain by using Analytical Hierarchy Process: A case study. *International Journal of Applied Optimization Studies, 1*(01), 49-58.

Bali, S., & Amin, S. S. (2017). An analytical framework for supplier evaluation and selection: A multi-criteria decision making approach. *International Journal of Advanced Operations Management, 9*(1), 57-72.

Das, D., & Saha, A. (2016). Analytical HierarchyProcess based supplier selection methodology: A framework and application. *International Journal of Reliability and Safety, 10*(2), 125-144.

Deepika, M., & Kannan, A. K. (2016). Global supplier selection using intuitionistic fuzzy Analytic Hierarchy Process. In *2016 International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT)* (pp. 2390-2395).

Deng, X., Hu, Y., Deng, Y., & Mahadevan, S. (2014). Supplier selection using AHP methodology extended by D numbers. *Expert Systems with Applications, 41*(1), 156-167.

Fu, Y. K. (2019). An integrated approach to catering supplier selection using AHP-ARAS-MCGP methodology. *Journal of Air Transport Management, 75*(March), 164-169.

Haq, A. N., & Kannan, G. (2006). Fuzzy Analytical Hierarchy Process for evaluating and selecting a vendor in a supply chain model. *The International Journal of Advanced Manufacturing Technology, 29*(7-8), 826-835.

Jain, V., Sangaiah, A. K., Sakhuja, S., Thoduka, N., & Aggarwal, R. (2018). Supplier selection using fuzzy AHP and TOPSIS: A case study in the Indian automotive industry. *Neural Computing and Applications, 29*(7), 555-564.

Jayant, A. (2018). An Analytical Hierarchy Process (AHP) based approach for supplier selection: An automotive industry case study. *International Journal of Latest Technology in Engineering, Management & Applied Science (IJLTEMAS), VII*(I), 102-114.

Joshi, A., Kale, S., Chandel, S., & Pal, D. K. (2015). Likert scale: Explored and explained. *British Journal of Applied Science & Technology, 7*(4), 396.

Kahraman, C., Cebeci, U., & Ulukan, Z. (2003). Multicriteria supplier selection using fuzzy AHP. *Logistics Information Management, 16*(6), 382-394.

Khalil, N., Kamaruzzaman, S. N., & Baharum, M. R. (2016). Ranking the indicators of building performance and the users' risk via Analytical Hierarchy Process (AHP): Case of Malaysia. *Ecological Indicators, 71*(December), 567-576.

Liberatore, M. J., Nydick, R. L., & Sanchez, P. M. (1992). The evaluation of research papers (or how to get an academic committee to agree on something). *Interfaces, 22*(2), 92-100.

Luthra, S., Govindan, K., Kannan, D., Mangla, S. K., & Garg, C. P. (2017). An integrated framework for sustainable supplier selection and evaluation in supply chains. *Journal of Cleaner Production, 140*, 1686-1698.

Luzon, B., & El-Sayegh, S. M. (2016). Evaluating supplier selection criteria for oil and gas projects in the UAE using AHP and Delphi. *International Journal of*

Construction Management, 16(2), 175-183.

Mathiyazhagan, K., Diabat, A., Al-Refaie, A., & Xu, L. (2015). Application of analytical hierarchy process to evaluate pressures to implement green supply chain management. *Journal of Cleaner Production, 107*(November), 229-236.

Min, H. (1994). International supplier selection: A multiattribute utility approach. *International Journal of Physical Distribution & Logistics Management, 24*(5), 24-33.

Nallusamy, S., Sri Lakshmana Kumar, D., Balakannan, K., & Chakraborty, P. S. (2016). MCDM tools application for selection of suppliers in manufacturing industries using AHP, Fuzzy Logic and ANN. *International Journal of Engineering Research in Africa, 19*, 130-137.

Pieter, M. S., Lamia, I. I., & Wattimena, F. Y. (2017). Decision Support System in giving recommendation for flat screen television purchase using Analytical Hierarchy Process (AHP) method. In *2017 Second International Conference on Informatics and Computing (ICIC)* (pp. 1-5).

Pjevcevic, D., Dimitrijevic, B., Bisevac, I. V., & Vukadinovic, K. (2018). Design process of dry bulk cargo handling at an inland port: Case study of Port Danube Pancevo. *International Journal of Industrial Engineering, 25*(2), 267-282.

Polat, G., & Eray, E. (2015). An integrated approach using AHP-ER to supplier selection in railway projects. *Procedia Engineering, 123*, 415-422.

Rajesh, G., & Malliga, P. (2013). Supplier selection based on AHP QFD methodology. *Procedia Engineering, 64*, 1283-1292.

Santoso, D., & Besral, A. M. (2018). Supplier performance assessment using Analytical Hierarchy Process method. *Sinergi: Jurnal Teknik Mercu Buana, 22*(1), 37-44.

Singawinata, I. P. (2007). The future of the Indonesian mining industry: Recommendations to policy makers. *Ritsumeikan Journal of Asia Pacific Studies, 22,* 99-113.

Stange, W. (1999). The process design of gold leaching and carbon-in-pulp circuits. *Journal of the Southern African Institute of Mining and Metallurgy, 99*(1), 13-25.

Tam, M. C., & Tummala, V. R. (2001). An application of the AHP in vendor selection of a telecommunications system. *Omega, 29*(2), 171-182.

UmaDevi, K., Elango, C., & Rajesh, R. (2012). Vendor selection using AHP. *Procedia Engineering, 38*, 1946-1949.

APPENDICES

Table 3 Main Criteria and Subcriteria

Main Criteria	Financial Aspect	Schedule	Quality	Operation	Service	Business Consideration	Health and Safety
Subcriteria	Foreign Exchange Rate (Forex Rate)	Manufacturing schedule	Endurance	Ease of Operation	After-Sales Service	Reputation	Sustainability
	Equipment Expenditure Cost	Delivery schedule	Durability	Spare Part Availability	Site Support	Communication	Health and Safety Compliance
	Installation Cost	Installation schedule	Quality Support	Training Access	Engineering Services	Expertise	Environmental Friendly
	Transportation Cost		Quality Assurance	Running Capacity	Commissioning Service	Contract and Agreement	
	Handling Cost			Compliance with Regulations			
	Cost of Service			Automation			
	Operation and Maintenance Cost			Efficiency			

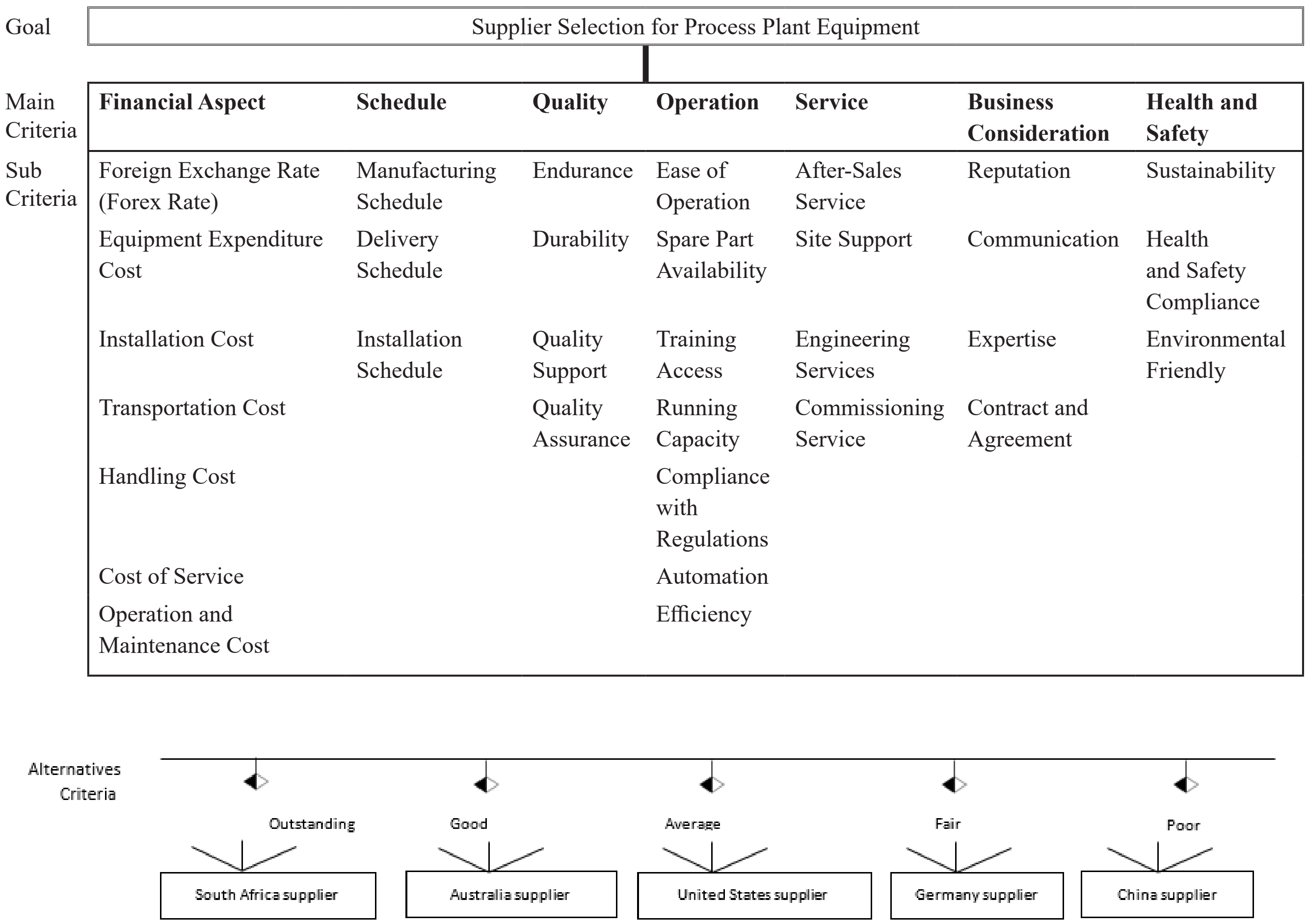

Figure 2 Hierarchy Diagram for Selecting the Process Plant Equipment

Table 4 Pairwise Comparison Matrix
for the Main Criteria

	Financial Aspect	Schedule	Quality	Operation	Service	Busines Consideration	Health and Safety
Financial Aspect	**1,0**	3,0	0,2	0,2	0,2	5,0	0,5
Schedule	0,3	**1,0**	0,3	0,3	5,0	3,0	0,3
Quality	0,2	3,0	**1,0**	0,2	5,0	7,0	1,0
Operation	5,0	3,0	5,0	**1,0**	5,0	5,0	5,0
Service	0,3	0,2	0,2	0,2	**1,0**	2,0	0,2
Busines Consideration	0,2	0,3	0,1	0,2	0,5	**1,0**	0,2
Health and Safety	2,0	3,0	1,0	0,2	5,0	5,0	**1,0**
Total	**9,1**	**13,5**	**7,9**	**2,3**	**21,7**	**28,0**	**8,2**

Table 5 A Normalized Matrix for the Main Criteria

	Financial Aspect	Schedule	Quality	Operation	Service	Business Consideration	Health and Safety	Priority Factor
Financial Aspect	0,11	0,22	0,03	0,09	0,01	0,18	0,06	0,099
Schedule	0,04	0,07	0,04	0,14	0,23	0,11	0,04	0,096
Quality	0,02	0,22	0,13	0,09	0,23	0,25	0,12	0,151
Operation	0,55	0,22	0,63	0,43	0,23	0,18	0,61	0,408
Service	0,04	0,01	0,03	0,09	0,05	0,07	0,02	0,043
Business Consideration	0,02	0,02	0,02	0,09	0,02	0,04	0,02	0,033
Health and Safety	0,22	0,22	0,13	0,09	0,23	0,18	0,12	0,169
								CR=0,08

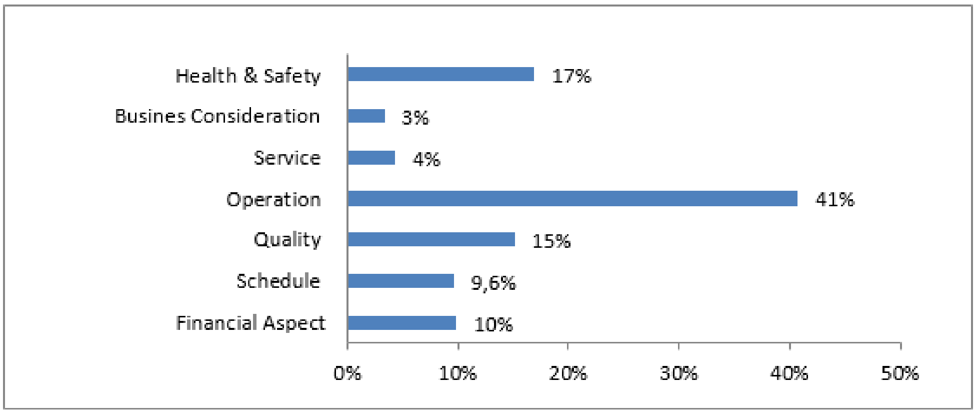

Figure 3 The Rank of Main Criteria in Percentage

Table 6 Pairwise Comparison Matrix for Subcriteria

Financial Aspect	Forex Rate	Equipment Expenditure Cost	Installation Cost	Transportation Cost	Handling Cost	Cost of Service	Operating and Maintenance Cost	Priority Factor
Forex Rate	0,03	0,02	0,02	0,01	0,01	0,01	0,08	**0,026**
Equipment Expenditure Cost	0,16	0,10	0,23	0,18	0,27	0,15	0,08	**0,166**
Installation Cost	0,23	0,05	0,11	0,18	0,19	0,22	0,11	**0,155**
Transportation Cost	0,10	0,02	0,02	0,04	0,11	0,01	0,06	**0,051**
Handling Cost	0,10	0,01	0,02	0,01	0,04	0,02	0,08	**0,041**
Cost of Service	0,16	0,05	0,04	0,25	0,11	0,07	0,08	**0,110**
Operating and Maintenance Cost	0,23	0,73	0,56	0,33	0,27	0,51	0,53	**0,451**
							λmax	**8,62**
							CR	**0,08**

Schedule	Manufacturing Durations	Delivery Durations	Installation Durations	Priority Factor	Quality	High Endurance	Quality support	Durability	Priority Factor
Manufacturing Durations	0,59	0,45	0,63	**0,56**	High Endurance	0,68	0,54	0,71	**0,64**
Delivery Durations	0,12	0,09	0,06	**0,09**	Quality support	0,10	0,08	0,05	**0,07**
Installation Durations	0,29	0,45	0,31	**0,35**	Durability	0,23	0,38	0,24	**0,28**
			λmax	**3,07**				λmax	**3,10**
			CR	**0,06**				CR	**0,08**

Operation	Ease of Operation	Spare Part Availability	Training Access	Running Capacity	Compliance With Regulation	Automation	Efficiency	Priority Factor
Ease of Operation	0,06	0,13	0,15	0,06	0,07	0,13	0,05	**0,09**
Spare Part Availability	0,03	0,06	0,15	0,08	0,05	0,09	0,06	**0,07**
Training Access	0,02	0,02	0,05	0,08	0,03	0,09	0,08	**0,05**
Running Capacity	0,43	0,32	0,24	0,39	0,41	0,22	0,45	**0,35**
Compliance With Regulation	0,12	0,19	0,24	0,13	0,14	0,13	0,11	**0,15**
Automation	0,02	0,03	0,02	0,08	0,05	0,04	0,03	**0,04**
Efficiency	0,31	0,25	0,15	0,19	0,27	0,30	0,23	**0,24**
							λmax	**7,66**
							CR	**0,08**

Service	After Sales Service	Site Support	Engineering Service	Commissioning Service	Priority Factor
After Sales Service	0,67	0,75	0,61	0,54	0,64
Site Support	0,13	0,15	0,26	0,23	0,19
Engineering Service	0,10	0,05	0,09	0,15	0,10
Commissioning Service	0,10	0,05	0,04	0,08	0,07
			λmax	**4,2**	
			CR	**0,08**	

Busines Consideration	Reputation	Communication	Expertise	Contract and Agreement	Priority Factor
Reputation	0,22	0,32	0,20	0,39	0,28
Communication	0,07	0,11	0,12	0,17	0,12
Expertise	0,67	0,54	0,60	0,39	0,55
Contract and Agreement	0,03	0,04	0,09	0,06	0,05
				λmax	**4,2**
				CR	**0,08**

Health and Safety	Sustainability	Health and Safety Compliance	Environmental Friendly	Priority Factor
Sustainability	0,43	0,47	0,27	0,28
Health and Safety Compliance	0,43	0,47	0,64	0,12
Environmental Friendly	0,14	0,07	0,09	0,55
			λmax	**3,1**
			CR	**0,09**

Table 7 Local Weight and Global Weight
for Main Criteria (Ordered) and Subcriteria

Main Criteria	Local Weights	Subcriteria	Local Weights	Global Weights
Operation	0,41	Ease of Operation	0,09	0,0369
		Spare Part Availability	0,07	0,0295
		Training Access	0,05	0,0208
		Running Capacity	0,35	0,1431
		Compliance With Regulation	0,15	0,0620
		Automation	0,04	0,0160
		Efficiency	0,24	0,0992
Quality	0,15	High Endurance	0,64	0,0973
		Quality support	0,07	0,0112
		Durability	0,28	0,0428
Financial Aspect	0,099	Forex Rate	0,03	0,0026
		Equipment Expenditure Cost	0,17	0,0164
		Installation Cost	0,16	0,0153
		Transportation Cost	0,05	0,0051
		Handling Cost	0,04	0,0040
		Cost of Service	0,11	0,0108
		Operating and Maintenance Cost	0,45	0,0446
Schedule	0,096	Manufacturing Durations	0,56	0,0535
		Delivery Durations	0,09	0,0087
		Installation Durations	0,35	0,0341
Health and Safety	0,169	Sustainability	0,39	0,0659
		Health and Safety Compliance	0,51	0,0865
		Environmental Friendly	0,10	0,0170
Service	0,04	After Sales Service	0,64	0,0279
		Site Support	0,19	0,0084
		Engineering Service	0,10	0,0042
		Commissioning Service	0,07	0,0029
Business Considerationa	0,03	Reputation	0,28	0,0094
		Communication	0,12	0,0039
		Expertise	0,55	0,0183
	0.03	Contract and Agreement	0,05	0,0017
			Total	**1,0000**

Table 8 The Rank of Subcriteria

Subcriteria	Global Weight
Running Capacity	0,143
Efficiency	0,099
High Endurance	0,097
Health and Safety Compliance	0,086
Sustainability	0,066
Compliance With Regulation	0,062
Manufacturing Durations	0,054
Operating and Maintenance Cost	0,045
Durability	0,043
Ease of Operation	0,037
Installation Durations	0,034
Spare Part Availability	0,030
After Sales Service	0,028
Training Access	0,021
Expertise	0,018
Environmental Friendly	0,017
Equipment Expenditure Cost	0,016
Automation	0,016
Installation Cost	0,015
Quality support	0,011
Cost of Service	0,011
Reputation	0,009
Delivery Durations	0,009
Site Support	0,008
Transportation Cost	0,005
Engineering Service	0,004
Handling Cost	0,004
Communication	0,004
Commissioning Service	0,003
Forex Rate	0,003
Contract and Agreement	0,002

Table 9 A Normalized Matrix for Criteria

	O	G	A	F	P	Weight
O	0,560	0,642	0,524	0,429	0,360	**0,503**
G	0,187	0,214	0,315	0,306	0,280	**0,260**
A	0,112	0,071	0,105	0,184	0,200	**0,134**
F	0,080	0,043	0,035	0,061	0,120	**0,068**
P	0,062	0,031	0,021	0,020	0,040	**0,035**

Table 10 AHP Model for Supplier Evaluation

Criteria	Sub- Criteria	South Africa		Australia		United States		Germany		China	
		Rating	Total Score	Rating	Total Score	Rating	Total Score	Rating	Total Score	Rating	Total Score
Operation	Ease of Operation	F	0,002	G	0,010	G	0,010	G	0,010	F	0,002
	Spare Part Availability	F	0,002	G	0,008	G	0,008	G	0,008	F	0,002
	Training Access	F	0,001	G	0,005	G	0,005	G	0,005	F	0,001
	Running Capacity	G	0,037	O	0,072	O	0,072	O	0,072	F	0,010
	Compliance With Regulation	G	0,016	G	0,016	G	0,016	G	0,016	F	0,004
	Automation	P	0,001	G	0,004	G	0,004	O	0,008	P	0,001
	Efficiency	P	0,003	A	0,013	G	0,026	G	0,026	P	0,003
Quality	High Endurance	A	0,013	A	0,013	A	0,013	G	0,025	P	0,003
	Quality support	A	0,001	G	0,003	G	0,003	F	0,001	P	0,000
	Durability	A	0,006	G	0,011	G	0,011	F	0,003	P	0,001
Financial Aspect	Forex Rate	G	0,001	F	0,000	P	0,000	F	0,000	O	0,001
	Equipment Expenditure Cost	G	0,004	A	0,002	F	0,001	F	0,001	O	0,008
	Installation Cost	G	0,004	A	0,002	A	0,002	A	0,002	O	0,008
	Transportation Cost	A	0,001	G	0,001	A	0,001	A	0,001	O	0,003
	Handling Cost	A	0,001	A	0,001	A	0,001	A	0,001	O	0,002
	Cost of Service	F	0,001	F	0,001	F	0,001	A	0,001	O	0,005
	Operating and Maintenance Cost	F	0,003	A	0,006	P	0,002	A	0,006	O	0,022
Schedule	Manufacturing Durations	A	0,007	G	0,014	G	0,014	A	0,007	G	0,014
	Delivery Durations	A	0,001	A	0,001	A	0,001	A	0,001	G	0,002
	Installation Durations	A	0,005	A	0,005	A	0,005	F	0,002	G	0,009
Health & Safety	Sustainability	F	0,004	G	0,017	G	0,017	G	0,017	P	0,002
	Health and Safety Compliance	A	0,012	O	0,043	O	0,043	O	0,043	F	0,006
	Environmental Friendly	A	0,002	A	0,002	G	0,004	O	0,009	F	0,001
Service	After Sales Service	F	0,002	G	0,007	G	0,007	A	0,004	P	0,001
	Site Support	P	0,000	G	0,002	G	0,002	F	0,001	P	0,000
	Engineering Service	A	0,001	O	0,002	G	0,001	F	0,000	P	0,000
	Commissioning Service	P	0,000	O	0,001	G	0,001	F	0,000	P	0,000
Business Consideration	Reputation	F	0,001	O	0,005	O	0,005	O	0,005	P	0,000
	Communication	A	0,001	G	0,001	G	0,001	G	0,001	P	0,000
	Expertise	A	0,002	G	0,005	G	0,005	G	0,005	F	0,001
	Contract and Agreement	A	0,000	G	0,000	O	0,001	G	0,000	F	0,000
	Total		**0,135**		**0,275**		**0,282**		**0,281**		**0,116**

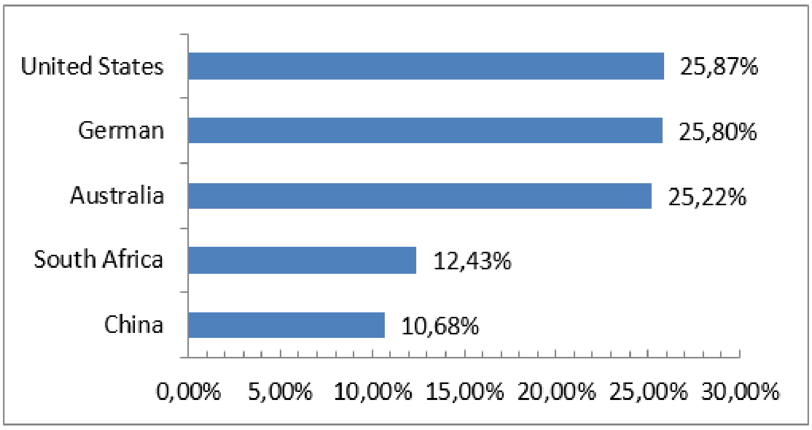

Figure 4 The Rank of the Suppliers in Percentage

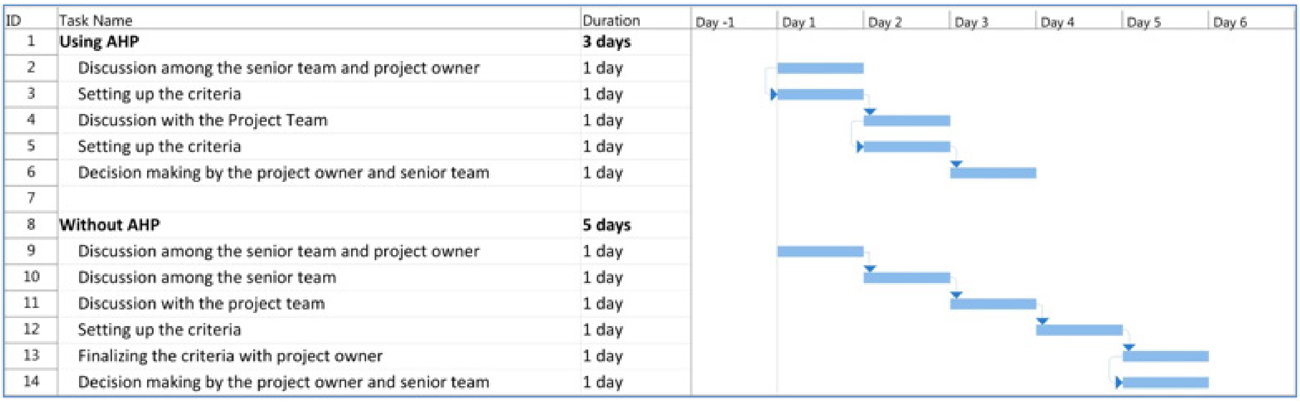

Figure 5 The Schedule Comparison for Using AHP and without Using AHP or Normal Process

Table 11 Resource Allocation and Total Hours

Resources	**Using AHP (Total hours allocated)**	**Without AHP (Total hours allocated)**
Senior Project Team	320	320
Subordinate Project Team	192	96
Total	**512**	**416**

Table 12 The Summarized Survey Result about the AHP Process

	Respondents				
	Strongly Disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
The final decision	0	0	6	10	16
In percentage	0%	0%	19%	31%	50%
Usage of the same tools for decision-making in critical items	0	4	8	8	12
In percentage	0%	13%	25%	25%	38%