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Using Analytical Hierarchy Process for Double Auction to Optimize Financial Performance of Private Higher Education Institutions

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Internal factors and external factors are used to measure the performance of higher education institutions. Internal factors include those whose criteria come from within the organization, while external factors are those whose criteria come from outside the organization. Of these two factors, measurement criteria that can help in decision-making about the development and expansion of higher education competence, including financial criteria, are needed. This study examines the optimization of the financial performance of private higher education institutions by applying the Analytic Hierarchy Process method and a proposed double auction framework. Financial criteria are critical to supporting the development and enhancing the competency of higher education institutions. The Analytical Hierarchy Process is used to prioritize 19 sub-criteria, with the Teaching Process Operational Cost Development sub-criterion scoring highest for each operational criterion. The double auction framework is proposed to facilitate decision-making for the development and further competence of private higher education institutions. This paper represents an important contribution to the evaluation of the financial performance of private higher education institutions by using a novel approach that incorporates a double auction framework.

1. Introduction

Current developments in technology encourage all stakeholders to enhance every aspect, including the social, political, commercial, educational, and financial spheres [1-3]. Technological advancements are also the foundation for the success of every organization, both private and public, for-profit and non-profit [4]. With these technological advancements compel leaders to improve every organization they oversee, including educational institutions. There are both government-owned and private universities [4].

Private tertiary institutions in Indonesia are expanding rapidly, from diplomas to universities, according to the Higher Education forlap data in 2017 there were 3,940 private tertiary institutions [5]. With the development of these tertiary institutions forcing higher education leaders to be able

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to compete with each other and compete in their respective fields because there must be reliable criteria to always be a reference in measuring and evaluating performance [6-8]. Without excellent and reliable criteria, decision-makers at tertiary institutions may be less precise in designing and developing tertiary institutions, rendering them uncompetitive [8].

Internal factors and external factors are utilized to measure the efficacy of higher education institutions. Internal factors are internal performance measurement factors, whereas external factors are performance measurements based on criteria from outside the organization [4,6-7]. From these two factors, it is necessary to derive measurement criteria that can aid in the development and expansion of competence in tertiary institutions [9-11].

In terms of internal and external factors, criteria measured by consumers, business processes, organizational development, and the financial sector can assist leaders in making decisions regarding the development and enhancement of tertiary competence [12-14]. These criteria can assist decision-makers in determining the direction of sustainable tertiary development [14-16]. The external criteria can be derived from consumers, stakeholders, and organizational development, while the internal criteria can be derived from business processes and finance [17].

The criterion in finance must be a priority in the administration of tertiary institutions due to their importance in supporting the development and increasing the competence of tertiary institutions [18]. Profit is the distinction between universities' prior focus on the financial aspects of the incoming and outgoing money sector [19]. However, a greater emphasis will be placed on enhancing the caliber of tertiary institutions so that their development and competition can be sustained. To measure these financial criteria, a method that can rank each criterion is required [20].

Increasing competence and developing higher education is seen from the financial aspect, then the criteria that are obtained are then lowered or hierarchized using the Analytical Hierarchy Process (AHP) method because the AHP method is a tool that is effective in deriving or hierarchizing and modeling multi-criteria problems or with the other intention [17, 21-22]. AHP can measure judgments using pairwise comparisons that can provide subjective considerations so that they can assist in decision-making [23]. The AHP criteria which will be used to support decision-making to improve competence and the development of tertiary institutions must have weights and priorities from each criterion so that with these weights and priorities the decision-maker can know what must be done in developing and improving the competence of tertiary institutions [24].

This study contributes to assisting decision-makers in private higher education institutions in Indonesia to establish criteria, weights, and priorities that emphasize financial aspects. Consequently, the purpose of this study is to determine the criteria for measuring the financial aspects from those that are essential to use to those that are not so important to use, so that the use of finance can be more precisely targeted. The outcome of the study is proposed for a double auction framework that assist financial management. So that with proper financial management, decisions regarding the development of tertiary institutions can be made, and the quality of these tertiary institutions can be enhanced so that the desired objectives of higher education can be more clearly defined.

2. Literature

2.1 Analytical Hierarchy Process

Professor Thomas L. Saaty, a mathematics professor at the University of Pittsburgh, United States, developed a method for making decisions in the early 1970s. Saaty's Analytic Hierarchy Processes (AHP). This method was created because this method was extended to analyze allocation requirements and resource planning that were inadequate for military applications.

AHP is an analytical instrument that can be used to make decisions in situations with complex factors, particularly subjective decisions [23]. AHP generates a structured method for determining

values and weights for multi-criteria problems and standardizing them so they can be compared and a decision made [22-24]. AHP is defined as one of the approaches used in fundamental analysis for making multivariate decisions or optimizations. The essence of AHP is a complete decision-making model that takes both qualitative and quantitative factors into account. The AHP decision-making model essentially attempts to address all of the shortcomings of the preceding approach. AHP also enables system structures and environments to interact with components before integrating them through the measurement and management of system fault effects [23, 24].

AHP is an analytical instrument that can be used to make decisions on conditions with complex factors, particularly if the decision is highly subjective. AHP can break down complex, unstructured, structured, and dynamic problems into their parts, which are hierarchically organized. The preparation of this hierarchy is the most essential step in AHP's application as a model of the desired problem solution. The compilation of this hierarchy requires innovative thought, information gathering, information grafting, the process of remembering, the perspective of the parents, and development. In practice, there is no standard method for developing objectives, criteria, and other elements of the hierarchy. Suspensions of the hierarchy are multilinear and consist, from top to bottom, of the most common and least controllable factors, the most general and least controllable factors, and the most concrete and controllable factors. Following are the benefits of the AHP method [24, 25]:

- 1) The hierarchical structure, as a result of the selected criteria to the deepest sub-criterion.
- 2) Taking into account the validity that has the tolerance of the in-consistency of the various criteria and alternatives chosen by the decision maker
- 3) Taking guesses of resistance barriers or sensitivity analysis outcomes to make decisions.

2.2 Business Intelligence (BI)

Business Intelligence (BI) is a collection of tools that create, access, and manipulate data interactively and provide managers and business analysts with sufficient analysis to improve and enhance decision flows [26]. Business Intelligence is a production process in which information is the primary material and knowledge is the end product. It is therefore all about accumulating, archiving, exploring, and delivering data, transforming it into knowledge and information. Its purpose is to aid managers in making better business decisions and provide more precise, valid, and expressive data. [26].

Khatibi *et al.*, [26] examined the Deployment of a business intelligence model to evaluate Iranian national higher education. According to the findings of their research, the allocation of resources, technical efficiency, and managerial effectiveness are among the primary goals of the government's national higher education programs for developing nations, including those in the Middle East. The dispersion of relevant data sources and the complexity of the higher education system's dynamism permit the development of an integrated, intelligent system with a multidimensional view of the current situation.

Abdullah *et al.*, [27] have researched the analysis of business intelligence using ERP for higher education to design a multi-domain education model (eduMDBI). Based on this research, it was determined that EduMDBI consists of three main business intelligence domains: Educational Business Intelligence (EduBI) to produce various types of analytical and predictive reports related to academic data, Financial Business Intelligence (FBI) to enable decision makers to obtain the necessary financial information, and Human Resource Business Intelligence (HRBI) This study concluded that the EduMDBI model can enhance the process of obtaining valuable, analytical, and predictive data and aid in making the correct decision at the appropriate time. Business Intelligence Applications can be

designed and developed based on the EduMdbI model to include additional ERP sub-modules and business intelligence domains [27].

2.3 Double Auction

Double auction is a negotiation protocol that defines interaction boundaries between participants. It is a many-to-many auction-based protocol that has been used to manage symmetrical bids and asks respectively submitted by a large number of consumers and providers [28,29,30].

In the context of the Virtual Financial Community (VFC), Peng *et al.*, [31] proposed a double auction mechanism that considered both price and non-price attributes. This mechanism aimed to create fair and reasonable matches between buyers and sellers. Expanding on the idea of auctions, Sun and Guo [32] extended the auction method for the re-allocation of emission permits at the China Beijing Environment Exchange (CBEE). Their goal was to meet pollution reduction targets effectively.

introduced an agent-based groundwater market model to analyze the economic and hydrologic impacts of different market mechanisms [33]. These mechanisms, based on the cap-and-trade scheme, included uniform price double-auctions and discriminatory price double-auctions. The authors found that current auction methods often overlook the existence of quantity discounts and sought to address this gap in their research. Liang *et al.*, [34] applied auction methods to the logistics services procurement market. Their goal was to fill the research gap regarding the consideration of quantity discounts in current auction practices.

In response to the dynamic nature of cloud supply and demand, Reza *et al.*, [35] proposed a cloud priority-based dynamic online double auction mechanism (PB-DODAM). This mechanism aligned with the time constraints of agents involved in the cloud market. Recognizing the inefficiencies and limitations introduced by the involvement of third parties in the auction process, Artour [36] explored the use of blockchain technology to address these issues. They emphasized the transparency and flexibility provided by blockchain in auction processes. Lastly, Singhal *et al.*, [37] put forward a Feedback-based Combinatorial Fair Economical Double Auction Resource Allocation Model (FCFEDARA). This model assessed the authenticity of resource providers based on their offered prices and customer feedback.

3. Research Methodology

This study applies a quantitative approach involving the distribution of questionnaires to respondents in two phases and the use of purposive judgment sampling; the criteria for respondents are outlined in the following table:

Table 1
Criteria of respondent

No	Position	Years Of Service
1	Rector	>= 5 year
2	Vice-Rector	>= 5 year
3	Dean	>= 5 year
4	Vice Dean	>= 5 year
5	Head of The Finance	>= 10 year

A questionnaire was disseminated based on the information in the table above. Based on the diagram below, this investigation was conducted in three phases:

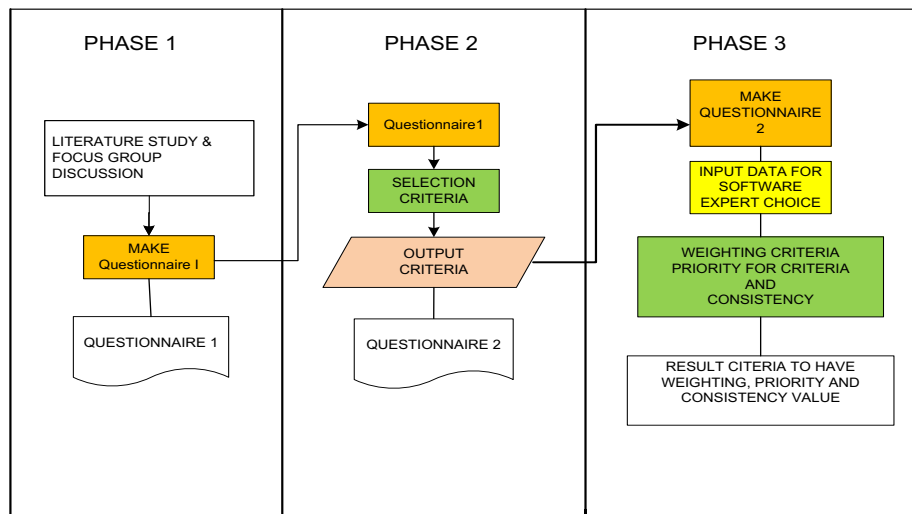


Fig. 1. Design Research

The first phase consists of a literature review and FGD to obtain references for the questionnaire's criteria. After completing the first section of the questionnaire, the next step is to select the criteria that will be used to make measurements in decision-making for the development and enhancement of Higher Education competencies by employing a linked scale with a formula.

$$75\% \times (\sum \text{Respondent} \times \text{Maximum Score}) \tag{1}$$

After selecting the criteria, the next step is to create the second stage of the questionnaire, from which the questionnaire is filled out and then selected using the pairing method and the corresponding formula 2. After collecting the results, it is necessary to input and analyze data using Expert Choice.:

$$R = [(1+R_1) (1+R_2) (1+R_3).....(1+R_n)]^{1/n} - 1 \tag{2}$$

Detail:

R₁...R_n= result of respondent 1 for respondent n

3. Results and Analysis

The followings are the results and analysis of data on financial criteria that will be used to facilitate decision-making for the development of private higher education institutions and the further development of their competence.

3.1 Main Criteria

The main measure of Finance is comprised of four criteria, the highest-scoring of which is a focus on cost and the lowest-scoring of which is a donation, according to Table 2.

Table 2

Main Criteria

No	Criteria	Score
1	Cost Focus	0.395
2	Training and Development	0.208
3	Income Focus	0.266
4	Donation	0.134

3.2 Sub-Criteria

3.2.1 Cost focus criteria

The main criterion for focus cost has four sub-criteria that measure the performance of private higher education institutions, of the four sub-criteria the credit cost semester of a student has the highest value or score according to Table 3.

Table 3

Cost Focus Sub-Criteria

No	Sub-Criteria	Score
1	Credit Costs Semester Student	0.302
2	Percentage Salary staff for Operation Cost	0.256
3	Percentage of salary Management staff Each Operating cost	0.23
4	Percentage of Administrative Costs for Each Operating Cost	0.213

3.2.2 Revenue Focus Criteria

The main criteria for revenue focus have five sub-criteria that measure the performance of private higher education institutions five. The Percentage Number of Earnings from the Number of Operations has the highest value or score according to Table 4.

Table 4

Revenue Focus Criterion Sub-Criteria

No	Sub-Criteria	Score
1	Percentage Number of Earnings From Number of Operations	0.244
2	Realization of revenue Compared to budgetary plans	0.215
3	Fund Management Document which includes Planning the Receiver, Allocation, Reporting, Audit, Monitoring and Evaluation, and stakeholder accountability.	0.192
4	Financial audit reports by external auditors that are transparent and accessible to all stakeholders	0.188
5	Internal Monitoring and Evaluation System for more efficiency, Transparent and compliance with applicable Financial Rules	0.161

3.2.3 Training and development criteria

The main criteria of the Training and Development Criteria have four sub-criteria which measure the performance of private higher education institutions of four sub-criteria Development

Operational Costs for the teaching process for each operation cost has the highest value or score according to Table 5.

Table 5

Training And Development Sub-Criteria

No	Sub-Criteria	Score
1	Development Operational Costs for the teaching process for each operating cost	0.328
2	Use of funds for infrastructure and human capital investments	0.256
3	Use of Funds for Research Operations	0.211
4	Use of Funds for Community Service Operations	0.205

3.2.4 Donation criteria

The main criteria for the Donation of Criteria have six sub-criteria that measure the performance of private higher education institutions. Of the four sub-criteria, the Percentage of Funds for Higher Education from students has the highest score or score according to Table 6.

Table 6

Donation Sub-Criteria

No	Sub-Criteria	Score
1	Percentage of Funds for Higher Education from students	0.217
2	Education Income Ratios Each Service Fee	0.195
3	Percentage of funds not from Student to Total Income	0.163
4	Percentage of student contributions from Total income	0.156
5	Funds Received from Research in Tempo Three Years Ago	0.135
6	Funds Provided by the Community Service in the Last Three Years	0.133

3.3 Weights and Rankings

As shown in Table 7, the outcomes of data processing are the weights of each criterion and sub-criteria from a financial perspective. These weights are then ranked from highest to lowest value.

3.4 Graph of Weights and Rankings

The weight and ranking graphs show that the highest weight of each sub-criteria is taken from Table 7. So that you get a graph that has the highest to lowest weight values, as shown in Figure 2 below.

Following the results of data processing in this study, the criterion with the highest score is Development Operational Costs for the teaching process for each operation cost; this criterion is the primary focus for private higher education institutions in improving the performance and quality of higher education institutions. The teaching process for each operating cost at private higher education institutions must be a concern because the operational costs of teaching developers significantly affect the quality of higher education institutions, and if the operational costs of teaching operational are not on target, it will have an impact on the financial losses that have been issued,

which will also have an impact on the quality of private tertiary institutions, with the cost of developing teaching operations that are not on target.

3.5 Double Auction framework

Based on the results and analysis of data on financial criteria, a double auction framework is proposed to facilitate decision-making for the development of private higher education institutions and the further development of their competence. In the context of higher education, a double auction could serve several purposes.

- a) Resource Allocation: The most direct purpose of the auction could be to allocate financial resources for operational costs, infrastructure development, lab equipment or classroom space, or even human resources. The institutions or departments could bid for these resources based on their needs and capacities. Figure 3 shows the proposed double auction framework.

Table 7
 Weighting and Rangking Sub-Kriteria

Ranking	Sub Criteria	Weighting
1	Development Operational Costs for the teaching process for each operating cost	0.328
2	Credit Costs Semester Student	0.302
3	Percentage Salary staff for Operation Cost	0.256
4	Use of funds for infrastructure and human capital investments	0.256
5	Percentage Number of Earnings From Number of Operations	0.244
6	Percentage of salary Management staff Each Operating cost	0.23
7	Percentage of Funds for Higher Education from students	0.217
8	Realization of revenue Compared to budgetary plans	0.215
9	Percentage of Administrative Costs for Each Operating Cost	0.213
10	Use of Funds for Research Operations	0.211
11	Use of Funds for Community Service Operations	0.205
12	Education Income Ratios Each Service Fee	0.195
13	Fund Management Document which includes Planning the Receiver, Allocation, Reporting, Audit, Monitoring and Evaluation, and stakeholder accountability.	0.192
14	Financial audit reports by external auditors that are transparent and accessible to all stakeholders	0.188
15	Percentage of funds not from Student to Total Income	0.163
16	Internal Monitoring and Evaluation System for more efficiency, Transparent and compliance with applicable Financial Rules	0.161
17	Percentage of student contributions from Total income	0.156
18	Funds Received from Research in Tempo Three Years Ago	0.135
19	Funds Provided by the Community Service in the Last Three Years	0.133

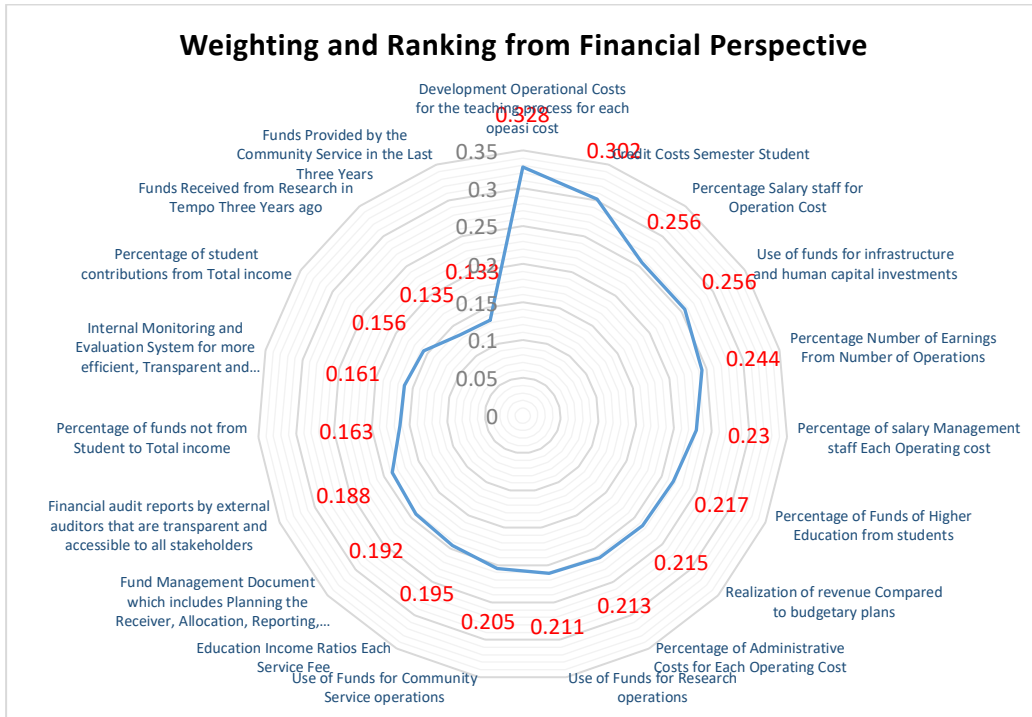


Fig. 2. Graph of Weights and Rankings

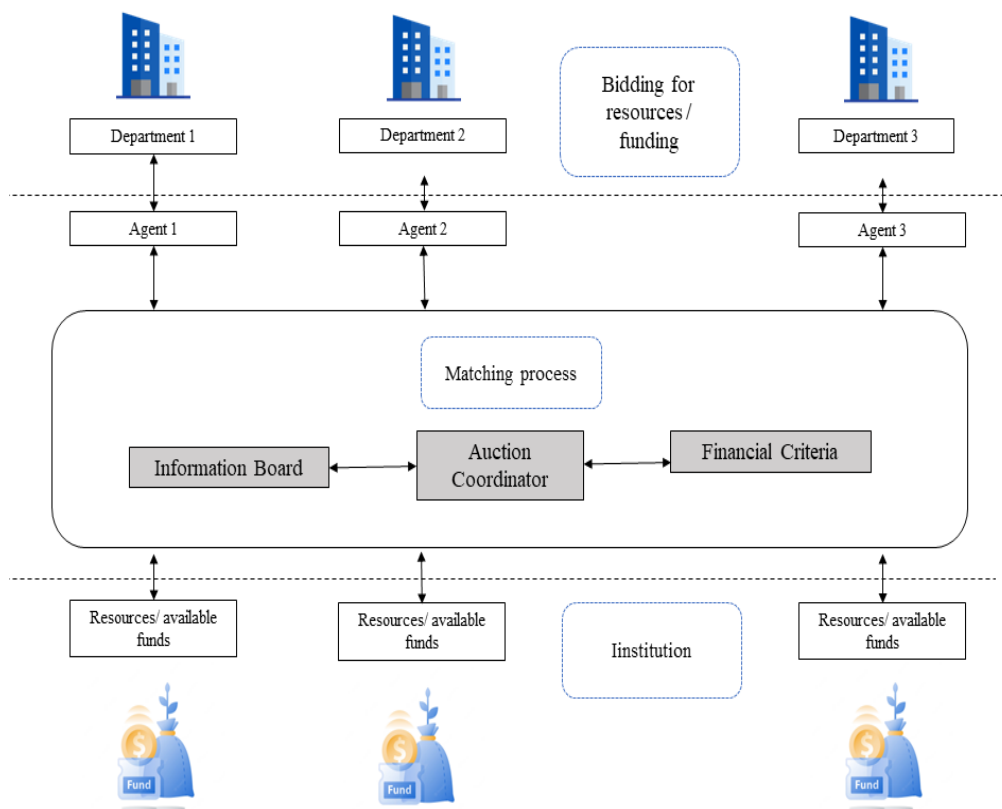


Fig. 3. Double auction for institution resource allocation

- b) Performance Evaluation: The results of the auction could serve as a performance metric. Institutions or departments that can secure more resources through the auction could be considered more efficient or high-performing. This could provide a market-based measure of performance that complements traditional academic performance metrics.
- c) Promoting Efficiency: The auction could incentivize institutions to operate more efficiently to be able to bid more competitively. This could drive improvements in areas like cost management, resource utilization, and financial management.

4. Conclusion

The use of tools such as the Analytic Hierarchy Process, double auction mechanisms, management control systems, and balanced scorecards can help institutions prioritize goals, improve decision-making, and achieve greater financial stability and competitiveness. These studies underscore the importance of financial performance metrics to college development and competitiveness, as well as the value of innovative approaches to financial management. By using these insights, universities and other higher education institutions can make informed decisions to effectively manage their resources and improve their overall performance.

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