Vendor management system improvement using PDCA and optimizing transporter vendor selection using fuzzy analytical hierarchy process

Fransisca Dini Ariyanti, Andrew Russell, Leonardo Setiawan

Industrial Engineering Department, Faculty of Engineering, Bina Nusantara University, Jakarta, Indonesia 11480

E-mail: dini.ariyanti@binus.ac.id, andrew.russell@binus.ac.id, leonardo.setiawan@binus.ac.id

Abstract. Transporter vendor is essential for a Fast-moving consumer goods factory to distribute processed palm oil and its derivatives to distributors, retailer and customers. The purpose of this research is to set a transporter vendor selection system based on the weighted criteria: price, reliability, flexibility and company qualification using the Fuzzy Analytical Hierarchy Process (FAHP) method. Followed by designing of Vendor management System (VMS) which will be used interactively by both the transporter vendor and the FMCG factory admin, so that the logistic process documentation is recorded properly. The FAHP selection results determined transporter C as the winner for the truck type of double colt diesel (CDD) and colt diesel ankle (CDE). And transporter G as the winner for the type of wing box truck (WB). The proposed VMS application design which carried out using Plan-Do-Check-Action (PDCA), House of Quality (HOQ), and User Centered Design (UCD), which contains 22 functional requirements for admin and 15 functional requirements for the transporter.

Keywords: Fuzzy Analytical Hierarchy Process (FAHP), Vendor Management Systems (VMS), Plan-Do-Check-Action (PDCA), House of Quality (HOQ), User Centered Design (UCD).

1. Introduction
The process of selecting transporter is crucial and needs to be done carefully to minimize errors that can lead to the failure of the transporter to meet company needs or even cripple the entire business process and damaged finished products. Criteria such as the price offered, reliability, qualifications, and flexibility are the company’s considerations in conducting the selection process.

The research conduct at PT XYZ, which is a public company for consumer and agribusiness products based on palm oil, such as harvesting oil palm trees, processing fresh fruit bunches (FFB) into crude palm oil (CPO), processing CPO into industrial and consumer products such as cooking oil, margarine, shortening, and biodiesel, and worldwide trade in palm oil products. Due to the large number of products that must be distributed nationally and exported abroad, a low price, reliable, flexible and qualified company is needed. Three types of vehicles used in transporting finished products from one point to another are colt diesel double (CDD) with capacity 2.5 tons, colt diesel ankle (CDE) with capacity 5.5 tons, and wingbox (WB) with capacity 18 tons. There are six 3PL, third party logistic transporter vendor. Despite the selection process begins by collecting complete data on the transporters along with the price offered, the selection is manual and only focusing on the cheapest price, without paying attention to other criteria. The impact are damaged finished products due to poor truck conditions, discrepancy between transporter key performance indicator (KPI) and factory target. Among Six transporter vendor only 50% reach factory KPI target. Especially
on rate of return of proof of delivery (POD) or delivery note, among six vendors, only two vendors reach the target. Missing of POD impact to financial losses, due to invoices that cannot be paid without POD. POD or delivery note is a document given from the factory to the transporter as proof that the goods have been received by the customer as well as proof of billing for shipping costs. In the transporter sourcing process, it was also found that the transporter profile data has been obtained is only stored in a spreadsheet which can be said to only be a procedural activity plus an irregular storage format. The data search was still carried out manually with a format that was not standardized so it was difficult to find specific data. Lack of mutual information with transporters and difficulties on monitoring status of the trucks used also contributed to the low KPI level. Problems also found when searching for filled RFP, Request for Price forms by transporter or quotation comparison document, which forms need to be made manually by copying them one by one on the spreadsheet. The company not yet install Vendor Management Systems (VMS) application, due to expensive cost, so the transporter vendor selection process still manual, subjective, and not standardized.

The purpose of this research is first, to set a transporter vendor selection system based on the weighted criteria: price, reliability, flexibility, and company qualification using the FAHP method. Second, designing of Vendor management System (VMS) which will be used interactively by both the transporter vendor and the FMCG, fast moving consumer goods factory admin, so vendor would select systematically, and the logistic process documentation is recorded properly. VMS would avoid missing delivery note by digitalized documents.

2. Literature Review
Fuzzy AHP is used to provide a systematic decision-making tool on the evaluation of third-party logistics service provider (3PL) especially for 3PL transportation providers, because the selection strategic alliance decisions is not easy, and is persistent, associated with uncertainty and complexity [1].

AHP is one of the most advantageous strategies to assess transportation issues. Above all else, any determination/need/choice issue comprises of different criteria and sub-criteria. Either objective or abstract contemplations or either quantitative or subjective data may assess with AHP strategy. Any degree of insights regarding the principal centre can be recorded or organized in this technique. By this way the review of the primary focus or the issue can be represented without any problem [2].

The effectiveness reached when develops an integrated approach, combining quality function deployment (QFD), fuzzy analytic hierarchy process (FAHP) approach, to evaluate and select the optimal third-party logistics service providers (3PLs) [3].

FAHP is one of the most helpful procedures to assess transportation issues [2]. It very well may be said that utilizing etymological factors makes the assessment measure more reasonable. Since assessment is not an accurate cycle and has fluffiness in its body. Here, the use of FAHP loads makes the application more practical and dependable. Comparison in deciding makes a comparative assessment or defines and implements data collection to obtain pairwise comparative data on elements of a hierarchical structure [4]. After using the deciding basic matrix, multiply the criteria in the matrix by the alternative matrix to get the priority vector. Then determine the weight sum vector by multiplying the line average with the basic Matix, and the consistency vector by dividing the weighted sum vector and the average of the rows. After getting the consistency vector, calculate the lambda and the consistency index which can be formulated as follow[5]:

\[
CI = \frac{\lambda_{max}}{n} - 1 \quad \text{[1]}
\]

After getting the Consistency Index (CI), to find the Consistency Ratio (CR) value, it can be calculated using the following formula [6]

\[
CR = \frac{CI}{RI} \quad \text{[2]}
\]

Fuzzy AHP has proven to be a very useful method in determining multi-criteria decision making [6]. Although conventional AHP is very good at extracting expert knowledge, it is still unable to reflect the human thinking style, where precise data is quite difficult to obtain[7]. Therefore, the fuzzy extension of AHP is applied which takes into account the uncertainty (uncertainty or insufficient
information) of the decision maker. Fuzzy sets and fuzzy numbers are formulated to infer vague answers or uncertain information in mathematical numbers. Fuzzy set is an objective class with a continuum value. Membership function in fuzzy sets places each membership value object in (0, 1). A tilde will be placed above the symbol as a fuzzy number marker. Triangle Fuzzy number (TFN). TFN can be denoted as \((l, m, u)\). the parameters \(l, m, u\) define the smallest possible value, the most promising value, and the largest value that represents the fuzzy event\[8\]. Each TFN has a linear representation on its right and left whose membership function can be defined as follows in formula 3 showing the triangular fuzzy number\[7\]:

\[
\mu_M = \begin{cases} 
0, & x < l, \\
\frac{x - l}{m - l}, & l \leq x \leq m, \\
\frac{u - x}{u - m}, & m \leq x \leq u, \\
0, & x > u 
\end{cases} 
\]…………………… (3)

Vendor Management Systems (VMS) is a management system for transporter or partner. VMS plays a role in providing an overview and comprehensive processes for the procurement of goods, payments, demand, delivery, and transporter performance \[9\]. Studies show that transporters must meet seven rules, namely: the right product, condition, quantity, time, consumer, place, and cost \[10\].

Plan, Do, Check, and Action or PDCA is a method used to improve a continuous process that occurs continuously like an endless circle \[11,12\]. This concept was first introduced by a quality management expert named Dr. William Edwards Deming. The PDCA cycle step are: First, Plan. The Plan stage is the stage carried out to determine the target or objectives to be achieved in improving the process or problem to be solved, then also determining the method that will be used to achieve the predetermined target. Second, Do or Implementation stage is the stage of implementing or implementing everything that has been planned in the Plan stage including carrying out the process, producing and collecting data which will then be used for the Check and Act stage. Third, the Check stage is the examination and review stage as well as studying the results of the implementation at the D stage. Make a comparison between the actual results that have been achieved with the targets set and the accuracy of the predetermined schedule. Fourth, The Action or Follow up stage is the stage for acting on the results obtained from the Check stage.

3. Research Methodology
In conducting research, the determination of the main problem is done using the 5W + 2H approach and Ishikawa Diagram and then studying the information related to the process. The theories used are Analytical hierarchy process (AHP), Fuzzy logic-Based Model for Decision Making, Vendor Management System (VMS), User Centered Design (UCD), Human Computer Interaction (HCI), HOQ, and PDCA. Due to the broad research object, the researcher determined several limitations of the problem to be studied, namely regarding the vendor management system and the selection process carried out in the procurement sourcing transporter division for consumer goods originating from the factory in Marunda, North Jakarta. Data obtained by brainstorming then used to determine customer needs, AHP weighting questionnaires, interviews, and system usability scale (SUS) questionnaires. The processed data includes fuzzy logic analytical hierarchy process (FAHP), 5W + 2H, Ishikawa Diagram, UCD, HOQ, Use case diagrams, VMS application mockup design, and SUS calculations. Furthermore, the data is analyzed in order to provide a deeper understanding and ends with drawing conclusions.

4. Result and Analysis
4.1. Fuzzy logic analytical hierarchy process (FAHP)
Based on the data obtained from the Fuzzy Logic Analytical Hierarchy Process (FAHP) questionnaire, the calculation stage is then carried out. Fuzzy Logic Analytical Hierarchy Process (FAHP) is used to determine which transporters will be selected for 3 types of truck, namely CDE, CDD, and WB based on predetermined criteria. The total criteria used in Fuzzy calculations Logic
Analytical Hierarchy Process (FAHP) consists of 4 criteria, namely price, flexibility transporter, reliability transporter, and company qualification. The first stage of the FAHP is decisive

| Table 1. Integrated fuzzy comparison matrix criteria to CDD criteria |
|-----------------|-----------------|
| Price | Reliability | Flexibility | CQ |
|-----------------|-----------------|-----------------|-----------------|
| Price | 1 | 1 | 1 | 1.2599 | 1.8171 | 1.2804 | 0.8736 | 1.4422 | 2.2804 | 0.4368 | 0.4093 | 1.1447 |
| Reliability | 0.4368 | 0.5003 | 0.7037 | 1 | 1 | 1 | 1.0000 | 1.3389 | 1.7100 | 0.6934 | 1.2599 | 2.0801 |
| Flexibility | 0.4368 | 0.6934 | 1.1447 | 0.5848 | 0.7469 | 1.0000 | 1 | 1 | 1 | 1.2599 | 1.8171 | 2.2804 |
| CQ | 0.8736 | 1.4422 | 2.2804 | 0.4097 | 0.7937 | 1.4422 | 0.4368 | 0.5003 | 0.7037 | 1 | 1 | 1 |

After the integrated fuzzy comparison matrix table has been obtained, the next step is to calculate the value of the fuzzy synthetic extent, where to calculate it using the following formula:

\[
S_i = \sum_{j=1}^{m} M_{gi} \times \left[ \sum_{i=1}^{n} \sum_{j=1}^{m} M_{gi} \right]^{-1}
\]

The following table shows the fuzzy sum and fuzzy synthetic extent of each row for CDD truck types based on criteria to criteria as shown in table 2 and 3.

| Table 2. Fuzzy Sum of Each Row Criteria to Criteria |
|-----------------|-----------------|-----------------|
| Price | 3.5703 | 4.9527 | 6.7236 |
| Reliability | 3.1302 | 4.1491 | 5.5838 |
| Flexibility | 3.2815 | 4.2574 | 5.4341 |
| CQ | 2.7911 | 3.7863 | 5.5254 |

| Table 3. Fuzzy Synthetic Extent Criteria to Criteria |
|-----------------|-----------------|-----------------|
| Price | 0.1534 | 0.2889 | 0.5264 |
| Reliability | 0.1345 | 0.2420 | 0.4372 |
| Flexibility | 0.1410 | 0.2483 | 0.4254 |
| CQ | 0.1200 | 0.2208 | 0.4326 |

The next step is to calculate the value of the degree of possibility, which is calculated using the previously obtained fuzzy synthetic event table. In calculating the degree of possibility, it is necessary to calculate each existing criterion and later the smallest value will be taken to become the degree of possibility for each criterion. Here is the formula used to calculate the degree of possibility as shown in table 4:

\[
\begin{align*}
1, & \quad \text{if } m_2 \geq m_1, \\
0, & \quad \text{if } l_1 \geq u_2, \\
\frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, & \quad \text{otherwise}
\end{align*}
\]

Furthermore, after the degree of possibility value has been obtained for each existing criterion, calculations are carried out to change the value of the degree of possibility into weights of criteria by defuzzifying or changing the fuzzy number to non-fuzzy. The following is the normalized value for CDD truck types based on criteria to criteria (table 5).
Table 5. Value of Normalization Criteria to Criteria CDD

| Criteria   | Price  | Reliability | Flexibility | CQ      |
|------------|--------|-------------|-------------|---------|
| Weight of Criteria | 0.283  | 0.243       | 0.246       | 0.228   |

The normalization value that has been obtained will then be calculated to obtain the weight vector value whereby looking at the total weight vector value it can be determined which transporters will be selected for the types of CDD, CDE, and WB truck. The calculation of the weight vector value is done by multiplying the value of weight vector to CDD criteria that has been obtained with all the values of the weight transporter to transporter (price, reliability, flexibility, and company qualification) and the results are added up. The following is an example table of calculating the total weight vector value for this type of CDD truck (table 6):

Table 6. Calculation of Weight Value Vector CDD

| Weight | A     | B     | C     | D     | E     | F     |
|--------|-------|-------|-------|-------|-------|-------|
| Price  | 0.283 | -     | 0.210 | 0.308 | 0.336 | 0.037 | 0.109 |
| Reliability | 0.243 | 0.166 | 0.004 | 0.366 | 0.210 | 0.254 | -     |
| Flexibility | 0.246 | 0.256 | 0.293 | 0.274 | -     | 0.017 | 0.160 |
| CQ     | 0.228 | -     | 0.400 | 0.350 | 0.250 | -     | -     |
| Total  | 1.00  | 0.103 | 0.223 | 0.323 | 0.203 | 0.076 | 0.070 |

In the calculation of the FAHP, after the weight value of the criteria to criteria, transporter to transporter (price), transporter to transporter (reliability), transporter to transporter (flexibility), and transporter to transporter (company qualification) has been obtained, then the calculation will be carried out to calculate which transporter will be the winner of all categories. For CDD truck types, procurement is recommended to choose transporter C as the winner. For CDE car types, procurement is recommended to select transporter C as the winner. For WB car types, procurement is recommended to choose transporter G as the winner.

The results and calculation formulas obtained will then become input to the VMS application where the calculation formulas will be implemented into the application analytics and the calculation results will be used as references in determining the transporter.

4.2. Plan, Do, Check, and Action (PDCA) Plan Phase

The plan stage aims to determine the causes of problems that occur and set standards. The process of identifying problems and targets to be achieved is carried out using the 5W + 2H method and Ishikawa diagrams. Based on the observations made, there are several obstacles that occur in practice, namely in the process of legal file checking, RFP, Request for Price / RFQ, request for quotation form filling, QCF, quotation comparison form, making, QCF updating, and the determinants of transporter selection, all of which occur in the value adding process. After the observation, a brainstorm was conducted with the procurement manager and category analyst of PT XYZ. The problem identification process is recapitulated using the 5W + 2H method which is shown in table 7 as follows.

Table 7. 5W + 2H explanation

| Question | Explanation | Question | Explanation |
|----------|-------------|----------|-------------|
| What's the problem? | 1. The transporter documents are mixed up after checking | Why did the problem occur? | 1. Work is still manual with a spread sheet |
| 2. Human error on the QCF input process | | 2. Transporter selection process which is based solely on price without considering historical KPIs and company capabilities |
| 3. Low KPI on some transporters | | Driver delays on returning POD. The company has considered buying software, but the price is high |
| 4. Low level of POD timekeeping | | | |
| 5. The transporter documents are mixed up after checking | | Where did this problem occur? | |
| 6. Human error on the | | | |
| | | Who is | |
| | | Procurement PT XYZ | |
| | | Procurement and transporter division | |
QCF input process
7. Low KPI on some transporters
   Low level of POD timekeeping
   responsible?
   How many improvements?
   Two improvements need to be made

| When did the problem occur? | During the new transporter selection period | How to fix? |
|-----------------------------|--------------------------------------------|-------------|
| 1. Determine a new transporter selection method |
| 2. Designing a transporter management system so that procurement can focus more on price negotiations |

The results from 5W + 2H were then investigated further to determine the root cause of the problem.

Figure 1. Ishikawa diagram

Based on the Ishikawa diagram in figure 1, the different price problems in QCF from the data entered by the transporter are caused by human factors, namely human error which is also caused by the large amount of data that needs to be transferred to QCF. In addition, there is also a method factor that is still manual which contributes to data errors. The mixed problem of legal documents is also caused by two factors, namely human and material factors. Failures caused by human factors are caused by human error and from material factors caused by documents that do not have a unique code or cannot be distinguished. After the causes and solutions are identified, a Transporter management system application design is carried out that can facilitate the problem. The questionnaire result data will then be entered into QFD as the Voice of Customer for further use as a basis for developing application features. In addition to QFD, the user centered design method is also implemented so that the application development process can be in line with user wishes and can be immediately evaluated in the event of a deviation.

4.3. House of Quality
The results obtained from the Ishikawa diagram method are further discussed with the user as a basis for determining customer needs that must exist in the application to be designed. Based on the information obtained by using the brainstorming method, information is obtained about the wishes of the customer in using the application regarding the transporter management systems.

House of Quality is one method of Quality Function Deployment which is used to translate wishes customer. House of Quality (HOQ) is used to find out what things are needed in making transporter management systems. The use of HOQ can also be used to determine technical requirement which one needs to be resolved first based on the calculated priority scale. House of Quality divided into six parts, customer needs, technical requirements, planning matrix, interrelationship matrix, correlation matrix, and design targets as shown in figure 2.

Based on the calculations carried out, the technical requirements that need to be prioritized first are the digitization process with a percentage of 48%, standardization of tabulations with a percentage of 19%, making simple designs with a percentage of 14%, integration with the unit with a percentage of 12%, and finally integration with legal division with a percentage of 7%.
4.4. User Centered Design

The UCD method is also applied in the process of designing a transporter management system application so that the process can be controlled, and the design made is in line with customer desires that have been obtained from the House of Quality (HOQ).

- Understanding and Defining User Context (Specify the context of use)

Users of this VMS application are the procurement division and transporter company who will register. The application will be used in all internal transporter or transporter selection processes that will run in the next period. Actor identification is used to find out more clearly about the subject and its role in operating the VMS system. The identification of actors can be seen in table 8.

- Determining User and Organizational Requirements (Specify User and Organizational Requirements)

Determination of user requirements can be seen from their functional requirements. The functional requirements for VMS application that will be designed are divided into two types, namely functional requirements for the admin level and the transporter level. The table of the functional requirements of the VMS application for admins and transporter shown in table 9.

---

**Figure 2.** House of Quality for Application Transporter Management Systems

**Table 8.** Actor Identification

| Actor      | Description                                                                 |
|------------|------------------------------------------------------------------------------|
| Admin      | Admin is the main user who operates the VMS system that can use features that are not provided in the application for transporters, including viewing all transporter profile data, analyzing transporter selection using FAHP, processing RFP data from all transporters, managing contracts, managing negotiation documents, create QCF, and monitor KPI of each transporter |
| Transporter| Transporter or in this case, the transporter company is a system user that can operate the system with limited features that have been provided such as managing profiles, monitoring KPIs themselves, uploading proof of delivery, filling out RFPs, uploading legal documents, filling out contract terms, and filling negotiation forms. |
| Function Name                          | Information                                                                 | Function Name                          | Information                                                                 |
|---------------------------------------|-----------------------------------------------------------------------------|---------------------------------------|-----------------------------------------------------------------------------|
| Login admin page                      | displays the login page for admin                                          | Transporter login page                | displays the transporter login page                                         |
| Admin dashboard                       | admin landing page view                                                     | Transporter dashboard                 | displays the transporter dashboard                                          |
| Overall KPI transporter                | displays KPI data for each transporter running                              | KPI individual transporter             | displays KPI or transporter performance                                     |
| Legal file documentation              | displays the legal documents of each transporter                            | Delivery schedule                     | display delivery schedule                                                   |
| Detail legal documents                | displays details of legal documents sent by the transporter                 | Upload POD                            | POD upload button                                                           |
| Legal document status                 | displays the status of legal documents being evaluated by the legal team    | Detail legal documents                | displays details of legal documents uploaded                               |
| Send legal documents                  | displays a send button that sends legal data to the legal team              | Legal document status                 | displays legal document status                                              |
| Contract terms & conditions form      | displays the contract terms form                                           | Upload legal documents                | legal document upload button                                                |
| Edit Form Terms and conditions form   | edit the contract terms form                                                | Form terms & conditions contract      | displays the contract terms form                                            |
| Mailing                               | displays the email page                                                     | Completion of contract T&C            | Fill out the contract terms form                                            |
| Transporter selection analytics       | displays the transporter selection analytics page                           | Transporter profile details           | display details of the transporter profile                                   |
| The final value of weighted           | displays historical transporter final rating weighting chart                 | Edit transporter profile               | edit profile                                                                |
| transporter selection                 |                                                                             | RFP Form                              | Displays the RFP form                                                       |
| List of transporters                  | displays the transporter data page                                          | Request RFP                          | request for RFP button                                                     |
| Detailed transporter data             | contains details of the transporter profile                                 | Completing the negotiation form       | negotiating price input column                                              |
| Edit transporter profile              | change the transporter data                                                 |                                       |                                                                             |
| RFP List                              | displays the RFP page that has been sent by the transporter                 |                                       |                                                                             |
| RFP Form                              | contains the RFP form                                                       |                                       |                                                                             |
| QCF List                              | contains a list of QCFs that have been created                              |                                       |                                                                             |
| QCF manufacture                       | make QCF                                                                     |                                       |                                                                             |
| Negotiation form                      | displays the negotiation column on the RFP                                  |                                       |                                                                             |
| Completing the negotiation form       | fill out the negotiation form                                               |                                       |                                                                             |
| Update QCF                            | update after the negotiation form is filled                                  |                                       |                                                                             |

4.5. Use Case Diagram

Use case diagram will visualize the relationship between actors and the VMS system being designed. The use case diagram for admins and transporters can be seen in the following figure.
Plan, Do, Check, and Action (PDCA) Phase Do
The do stage in PDCA is implementing the plans that have been made into the existing system and the third stage in user centered design is producing design solutions.

- **Produce Design Solution**

Dashboardadmin is designed to have various information and features contained in it, such as at top of the page, the admin can see the transporter performance indicator in the form of ratings to find out the performance of the transporter being contracted and allow corrective action if the KPI is not in accordance with the standard, namely 75% as shown in figure 4. The KPIs displayed are on time POD, On time Delivery, and fulfillment level. Then, below is a summary of the expenditures each month divided by the type of vehicle, namely the type of CDD, CDE and WB along with the invoice status that needs to be reviewed. The bottom part of the dashboard page contains the number of active and contracted transporters and there is a Kanban board to monitor the ongoing process in the procurement division.

The login page display for the transporter has the same wireframe as the admin, but differs in coloring. Transporter can register by pressing request access and the request will be sent to the admin who will then give access to the transporter by providing a standard username and password which can then be changed.

Plan, Do, Check, and Action (PDCA) Check Phase
The check stage aims to evaluate the repair solutions that have been made to determine whether changes have a good impact or vice versa. The evaluation stage in designing a VMS application will
use a system usability scale questionnaire to identify the level of usability that users perceive. The assessment of the SUS questionnaire can be seen in the following table 10.

| Gender | Question | SUS value |
|--------|----------|-----------|
| Women  | Q1 5 | 1 4 | 3 4 | 2 | 4 | 2 4 | 2 | 78% |

Rating the final score of SUS is 78%, which means that the application designed is in the good category with a high marginal rate. However, further application development is still needed so that the design becomes more intuitive and users can confidently use the application.

**Plan, Do, Check, and Action (PDCA) Action Stage**

The do stage in PDCA is the stage of determining the work process that will be used in the next process if the check stage is considered to provide improvement. Based on the results of evaluation at the check stage using the system usability scale (SUS) with a value of 78%, which means that VMS application’s design is good, the next step is to implement the use of the VMS application that has been designed. Later this application will help the process of collecting and storing transporter data, making RFPs, negotiating forms 1 and 2, making QCF, as well as onboarding vendors with cloud computing so that users do not need to combine data obtained manually and minimize human error.

**5. Conclusion**

First, transporter selection used the fuzzy logic analytical hierarchy process (FAHP) method because it could reflect human thinking styles and consider values that are unclear (fuzzy). Weighted criteria are price 0.283, reliability 0.243, flexibility 0.246, and company qualification 0.228. It is show almost balance between price criteria to other criteria. Second, the proposed improvement of the vendor management system is to transform the Procurement process into digital form, known as process digitization. The design of the mock-up application is carried out as an initial stage in which there are 22 functional requirements for the transporter and 15 functional requirements for the transporter application.

**References**

1. Yayla A Y, Oztekin A, Gumus A T and Gunasekaran A 2015 A hybrid data analytic methodology for 3PL transportation provider evaluation using fuzzy multi-criteria decision making International Journal of Production Research 53(20) 6097-113
2. Oguztimur S 2011 Why fuzzy analytic hierarchy process approach for transport problems?
3. He T, Lee C K M and Emrouznejad A 2012 Strategic logistics outsourcing: An integrated QFD and fuzzy AHP approach Expert Systems with Applications 39(12) 10841-50
4. Widiantoro S 2017 The Implementation of Analytical Hierarchy Process Method for Outstanding Achievement Scholarship Reception Selection at Universal University of BatamE&ES 97(1) 012003
5. Brunelli M 2015 Introduction to the Analytical Hierarchy Process, New York: Springer
6. AbdelAzim AI, Ibrahim AM and Aboul-Zahab EM 2017 Development of an energy efficiency rating system for existing buildings using Analytic Hierarchy Process–The case of Egypt Renewable and Sustainable Energy Reviews 71 144-25
7. Wang YM and Chin KS 2011 Fuzzy analytic hierarchy process: A logarithmic fuzzy preference programming methodology International journal of approximate reasoning 52(4) 541-53
8. Biswas TK, Akash SM and Saha S 2018 A fuzzy-AHP method for selection best apparel item to start-up with new garment Factory: A case study in Bangladesh International Journal of Research in Industrial Engineering 7(1) 32-50
9. Tanti Y and Patel P 2019 Effective Vendor Management International Journal of Commerce and Management Research 153-9
10. Żak J 2015 Comparative analysis of multiple criteria evaluations of suppliers in different industries Transportation Research Procedia 10 809-19
[11] Yunitasari E W 2019 Perbaikan Sistem Belajar Mahasiswa pada Mata Kuliah Statistik Industri dengan Metode Plan Do Check Action (PDCA) *Industrial Engineering Journal of The University of Sarjanawiyata Tamansiswa* **64**-76

[12] Fitriani 2018 PDCA Cycle and Kaizen Philosophy *Journal of Islamic Education Management* **625**-40