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Home > Archives > Vol 1, No 1 (1)

## Vol 1, No 1 (1)

October 2020

DOI: <https://doi.org/10.31098/ess.v1i1>

### Table of Contents

#### Articles

<b>Biochar Making Machines Design for Increasing Food Security</b> <i>Susila Herlambang, , AZ. Purwono Budi Santoso, Muammar Gomareuzzaman, Astrid Wahyu Adventri Wibowo</i>	PDF 1-10
<b>Alternative Environmental Management in The Split Making Industry</b> <i>J Purwanta, Suharwanto Suharwanto, Trismi Ristyowati</i>	PDF 11-17
<b>Development of Ngebel Volcano as Geoheritage and Tourism Education of Volcano, Electric Energy and Geothermal, Ponorogo, East Java</b> <i>Dwi Fitri Yudiantoro, Ratnaningsih Ratnaningsih, P Pratiknyo, Maheri Maheri, DS. Sayudi, I. Paramitahaty, W. Ismunandar, DG. Sampurno, R. Muhammad, M. Abdurrachman</i>	PDF 18-32
<b>Preliminary Design Calculation of Stress Corrosion Cracking (SCC) Machine</b> <i>Y Amalia, A. Sudiyanto, F. Rahmawati, S.U. Santoso, Z.N.Y. Pratama, E. Pujiyulianto</i>	PDF 38-45
<b>Production Results Forecasting Using Linier Regression Methods In UMKM KWT Suka Maju</b> <i>Heriyanto Heriyanto, Yuli Fauziah, Dyah Ayu Irawati</i>	PDF 46-51
<b>Application of An Environmental Friendly Work Area At Dinda Hayu Batik</b> <i>Jaka Purwanta, Y Siswanti, Trismi Ristyowati</i>	PDF 53-59
<b>Inventory Information System Design in PT.Adi Satria Abadi Indonesia</b> <i>Sigit Haryono Agus Ristono, Ahmad Muhsin, Nur Afni</i>	PDF 60-72
<b>Quality Management System In The Graduate Program in Industrial Engineering UPN "Veteran" Yogyakarta Using The CIPP Mode</b> <i>Sadi Sadi, Agus Ristono, Hidayat Saputra</i>	PDF 73-80
<b>A New Method In The AHP-Weighting Of Criteria For Supplier Selection</b> <i>Agus Ristono, Tri Wahyuningsih, Agus Munandar</i>	PDF 81-89
<b>Application Of Manure And Plant Spacing On The Growth Of Indigofera Ratoon</b> <i>Darban Haryanto, Ellen Rosyelina Sasmita</i>	PDF 90-95
<b>Groundwater Prediction Using Pole-Pole Configuration in Batulicin Area South Kalimantan</b> <i>Ajimas Pascaning Setiahadwibowo, Muchamad Ocky Bayu Nugroho, Eko Wibowo</i>	PDF 96-102
<b>Empowerment of Women Farmer Groups in Salamrejo Village Kulon Progo Regency Through Independent Production Of Organic Fertilizer</b> <i>Nanik Dara Senjawati, Liana Fatma Leslie Pratiwi</i>	PDF 103-109
<b>Development of Information System to Refute Single Tuition Fee Online (UKT) Case Study : Universitas Pembangunan Nasioanal "Veteran" Yogyakarta</b> <i>Rifki Indra Perwira, Djoko Prasetyo Adi Wijaya, Bagus Wiyono</i>	PDF 110-121
<b>Empowerment of Farmer Groups through Vegetable Verticulture and Manufacture of Liquid Organic Fertilizer</b> <i>Heti Herastuti, Heni Handri Utami, Ellen Rosyelina Sasmita</i>	PDF 122-128

#### QUICK MENU

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#### INFORMATION

» [For Readers](#)  
» [For Authors](#)  
» [For Librarians](#)

<b>Prototype Design of IoT Remote Monitoring System for Industrial Process Using Firebase Realtime Database</b> <i>Dessyanto Boedi Prasetyo, Hidayatulah Himawan, Wilis Kaswidjanti, Fhrezha Zeaneth</i>	PDF 129-138
<b>Community Empowerment in Making Cassava Leaf Tempe</b> <i>Maryana Maryana, Suwardi Suwardi, Sugeng Priyanto</i>	PDF 139-145
<b>3D Print Parameter Optimization: A Literature Review</b> <i>Tri Wibawa, Hasan Mastrisiswadi, Ismianti Ismianti</i>	PDF 146-151
<b>A Review of Coal Liquefaction Using Direct Coal Liquefaction (DCL) and Indirect Coal Liquefaction (ICL) Techniques</b> <i>Mitha Puspitasari, Mahreni Mahreni</i>	PDF 152-159
<b>Clustering K-Means Using SNORT Application For Denial Of Service Attacks</b> <i>Rifki Indra Perwira, Bagus Muhammad Akbar, Hari Prapcoyo</i>	PDF 160-170
<b>Carrying Capacity of Mercury Pollution to Rivers in the Gold Mining Area of Pancurendang Village, Banyumas</b> <i>Johan Danu Prasetya, Dian Hudawan Santoso, Eni Muryani, Tyka Ramadhamayanti, Bandhar Aji Sukma Yudha</i>	PDF 171-180
<b>Preliminary Step for Designing an Agent-Based COVID-19 Spread Model in Indonesia</b> <i>Ismianti Ismianti, Eko Nursubiyantoro, Astrid Wahyu Adventri Wibowo</i>	PDF 181-189
<b>Improving Porang ( Amorphophallus Mueller) As Beneficially Product For Farmers Community Around The Forest In Semanu District Gunung Kidul Regency</b> <i>Dwi Aulia Puspitaningrum, Sumarwoto Sumarwoto, O S Padmini</i>	PDF 190-198
<b>Characteristics of Coal and Coal Ash</b> <i>Edy Nursanto, Adi Ilcham</i>	PDF 199-204
<b>Analysis of Water Plant Utilization using Organic Substrate Combinations to Manage COD BOD Turbidity in Pit Lak</b> <i>Indun Titisariwati, Hadi Oetomo, Muhammad Tri Aditya, Waterman Sulistyana Bargawa</i>	PDF 205-213
<b>Identification of Groundwater Contamination by Hydrocarbon from Gas Station at Caturtunggal Area using Geoelectrical Methods</b> <i>Ayu Utami, Ajimas Pascaning, Wisnu Aji Dwi Kristanto, Wildan Rizky Isnaini</i>	PDF 214-222
<b>Application of Online Administration System for Practical Work(PW) in the Petroleum Engineering Department, Universitas Pembangunan Nasional "Veteran" Yogyakarta</b> <i>Dewi Asmorowati, Mia Ferian Helmy, Bambang Bintarto</i>	PDF 223-228
<b>Efficiency Evaluation of the Rolling Mills Production: A Data Envelopment Analysis Approach</b> <i>Apriani Soepardi, Mochammad Chaeron, Mira T. Kuncoro, Gunawan Wijiatmoko</i>	PDF 228-237
<b>Effect of Fertilizer Frequency on Growth Varieties of Dendrobium Orchid</b> <i>Heti Herastuti, Siwi Hardiastuti E.K</i>	PDF 246-252
<b>Design Text Mining for Anxiety Detection using Machine Learning based-on Social Media Data during COVID-19 pandemic</b> <i>Yuli Fauziah, Shoffan Saifullah, Agus Sasmito Aribowo</i>	PDF 253-261
<b>Study Of Added Value Differentiation Of Peranakan Etawa (PE) Goat Milk Products On Agro-Industry In Pakem District Sleman Regency</b> <i>Dwi Aulia Puspitaningrum, Liana Fatma Leslie Pratiwi, Alit Istiani</i>	PDF 262-268
<b>Extraction of Silica from Kalirejo Minerals, Kokap, Kulonprogo, Yogyakarta</b> <i>Tutik Muji Setyoningrum, Sri Wahyu Murni, Wibiana Wulan Nandari</i>	PDF 269-276
<b>Earthquake and Tsunami Threat in Lombok</b> <i>Indriati Retno Palupi, Wiji Raharjo</i>	PDF 277-283
<b>The Effects of VICOIL Bopanprog Usage as a Substitute for Crude Oil for Oil-Based Drilling Fluids</b> <i>KRT Nur Suhascaryo, Susila Herlambang, Hiras Pasaribu</i>	PDF 284-294
<b>Induction Of Banana Roots In Various Media And In Vitro Growth Regulators</b> <i>Rina Srilestari, Suwardi Suwardi</i>	PDF 295-300
<b>Geostatistical Modeling of Ore Grade In A Laterite Nickel Deposit</b> <i>Waterman Sulistyana Bargawa, Simon Pulung Nugroho, Raden Hariyanto</i>	PDF 301-310
<b>Non-Invasive Anemia Screening Using Nails and Palms Photos</b>	PDF

<i>Mangaras Yanu Florestiyanto, Nandha Juniaroesita Peksi</i>	311-318
<b>Recycling Metal Waste Made From Aluminum into Ingots: Using the Melting Method with a Crucible Furnace (Lift Out)</b> <i>Rika Ernawati, Tri Wahyuningsih, Untung Sukanto, Muhammad Fauzi Rizalsyah</i>	PDF 319-327
<b>Modeling of Crude Oil Types Classification Using the Naive Bayes Classifier Method</b> <i>Harry Budiharjo Sulistyarto, Dyah Ayu Irawati, Joko Pamungkas, Indah Widiyaningsih</i>	PDF 328-339
<b>Increased Productivity Of Empon-Empon Jamu To Meet Demand Due To The Covid-19 Pandemic (Case Study In Dronco Hamlet, Girirejo Village, Imogiri District, Bantul Yogyakarta Regency)</b> <i>Gunawan Madyono Putro, Prijoto Prijoto</i>	PDF 340-346
<b>Review Paper: The Study of Flow Behavior and Performance of Polymer Injection at Pore Scale Using Micromodel</b> <i>Dedi Kristanto, Boni Swadesi, Indah Widiyaningsih, Sri Wahyu Murni, Roiduz Zumar, Sinosa Husenido</i>	PDF 347-356
<b>Erosion and Flood Discharge Plans Analysis on The Capacity of The Dead River Lake</b> <i>Andi Renata Ade Yudono, Muammar Gomareuzzaman</i>	PDF 357-366
<b>A Techno-Economic Analysis of Geothermal Energy in West Java</b> <i>Allen Haryanto Lukmana, Mia Ferian Helmy</i>	PDF 367-375
<b>LoRaWAN Technologies to Enable Landslide Disaster Prone Areas Monitoring</b> <i>Awang Hendrianto Pratomo, Johan Danu Prasetya, Sylvert Prian Tahalea</i>	PDF 376-384
<b>Spatial filtering of Time Domain Induced Polarization (TDIP): Enhancement of spatial estimates of Mineralization at Gunung Parang Karangsambung Kebumen, Central Java</b> <i>Wrego Seno Giamboro, Wahyu Hidayat</i>	PDF 385-396
<b>Groundwater Potential in the Candi Abang Area Berbah, Sleman, Yogyakarta Based on Geological Conditions</b> <i>Wisnu Aji Dwi Kristanto, Rahmad Dwi Prasetyo</i>	PDF 397-409
<b>Study of Several Relationship of Fertility Parameters on Rice Production of Ciherang Variety on Regosol Soils in The Southern Slopes of Merapi, Yogyakarta, Indonesia</b> <i>E. A. Julianto, Partoyo Partoyo, Sri Suharsih</i>	PDF 410-419
<b>Identification of Student Area of Interest using Fuzzy Multi-Attribute Decision Making (FMADM) and Simple Additive Weighting (SAW) Methods (Case Study: Information System Major, Universitas Pembangunan Nasional "Veteran" Yogyakarta)</b> <i>Vynska Amalia Permadi, Riza Prapascata Agusdin, Sylvert Prian Tahalea, Willis Kaswidjanti</i>	PDF 420-428
<b>Improving The Quality Of Ceramic Products Through The Application Of The Taguchi Multi Response Method To Increase The Competitiveness Of Ceramic Ukm In The Global Era (Case Study At The Kasongan Ceramics Ukm Center, Bantul, Diy)</b> <i>Dyah Rachmawati L, Sutrisno Sutrisno</i>	PDF 429-439
<b>Technopreneurship Based Product Innovation: a Case Study on Small Entrepreneur</b> <i>Tri Wibawa, Hendro Widjanarko, Humam Santosa Utomo, Suratna Suratna, Endah Wahyurini</i>	PDF 439-444
<b>Early vegetative growth of tomatoes cultivated under different types and dosages of fertilizer applied in the drip irrigation system</b> <i>R.R. Rukmawati Brotodjojo, Oktavia S. Padmini, Awang H. Pratomo</i>	PDF 445-452
<b>The Effect of Pyrolysis Temperature on Charcoal Briquettes from Biomass Waste</b> <i>Sri Wahyu Murni, Tutik Muji Setyoningrum</i>	PDF 453-460
<b>Response to Availability of N Regosol and its Uptake by Tomatoes on Giving Gamal (<i>Gliricidia sepium</i>) at Different Times</b> <i>Lelanti Peniwiratri, Didi Saidi, Candra Muhammad Solikhin</i>	PDF 461-467
<b>Study Of Coliform And Escherichia Coli Bacteria Contamination In Part Of Gajahwong River Near Universitas Islam Negeri (Uin) Sunan Kalijaga Yogyakarta</b> <i>Agus Bambang Irawan, Herwin Lukito</i>	PDF 468-474
<b>Web-Based Information System Analysis Of DIY Women's Career Success Facing COVID-19</b> <i>Paryati Paryati</i>	PDF 475-488
<b>Growth Of Three Tomato Lines (<i>Lycopersicum Esculentum</i> Mill) Using Trichoderma Sp In Vegetative Phase</b> <i>Endah Wahyurini, Lagiman Lagiman</i>	PDF 489-495
<b>Gladiolus Plants As An Alternative To Agro-Ecotourism</b> <i>Ari Wijayani, Rina Srilestari</i>	PDF 496-503



<b>Resistivity Modeling of Universitas Pembangunan Nasional "Veteran" Yogyakarta Groundwaters</b> <i>Wrego Seno Giamboro</i>	PDF 504-512
<b>The response of Diaphorina citri to Various Guava Shoots</b> <i>Mofit Eko Poerwanto, Chimayatus Solichah, Adi Ilcham</i>	PDF 513-520
<b>Production Of Biodiesel Out Of Crude Palm Oil By Using NaOH Catalyst</b> <i>Danang Jaya, Tunjung Wahyu Widayati, Aurasafira Riesty Putrika, Bagas Pramudita Adi</i>	PDF 521-527
<b>Potential Land of Eucalyptus Industrial Forest for the Development of Sweet Sorghum in Player Gunungkidul Regency</b> <i>Mohammad Nurcholih, Ayu Utami, Tri Wibawa, Eko Srtihartanto</i>	PDF 528-536
<b>Presumption of Ground Water Depth Using the Schlumberger Configuration Geoelectrical Method</b> <i>Dian Hudawan Santoso, Berty Dwi Rahmawati</i>	PDF 537-551
<b>Effectiveness of Turbidity Removal by Direct Filtration</b> <i>Ekha Yogafanny, Titi Tiara Anasstasia, Vindy Fadia Utama</i>	PDF 552-561
<b>Determination Of Geotourism Area Using Geographic Information System</b> <i>Ketut Gunawan, Waterman Sulistyana Bargawa</i>	PDF 562-569
<b>Integrate of Geoelectric and Geomagnetic Methods to Construct Subsurface Model as Early Landslides Mitigation in Kalirejo, Kokap, Kulonprogo</b> <i>Hafiz Hamdalah, Eko Wibowo</i>	PDF 570-578
<b>Liquid Organic Fertilizer (LOF) and Its Use for Plants: Community Based Organic Waste Empowerment Solution in Dusun Gesikan Bantul</b> <i>Titi Tiara Anasstasia, Ika Wahyuning Widiarti, Eni Muryani, Supriasyah Supriasyah</i>	PDF 579-587
<b>Potential Preventive Analysis for The COVID-19 Pandemic Cases in Yogyakarta with Multiple Criteria Analysis Method</b> <i>Intan Berlianty, Irwan Soejanto, Mukh. Nasir Ramdhani</i>	PDF 588-596
<b>Modeling of A Low Salinity Waterflooding in Carbonate Reservoir</b> <i>Suranto Suranto, Ratna Widyaningsih, Hidayat Tulloh</i>	PDF 597-604
<b>Aquifer Types at Groundwater Drilling Locations in the Munggur Area and Its Surroundings, Gunungkidul Regency, Yogyakarta Special Region</b> <i>Purwanto Purwanto, Siti Hamidah Siti Hamidah, Intan Paramita Haty</i>	PDF 605-615
<b>Analysis Of Vulnerability Of Groundwater In Mining Area</b> <i>Tedy Agung Cahyadi, Rika Ernawati, Shenny Linggasari, Ilham Firmansyah</i>	PDF 616-628
<b>Leaf Litter Decomposition Rate by Utilizing Biological Agents to Control Pests and Increase Plant Growth of Red Chili</b> <i>Oktavia S. Padmini, R.R. Rukmowati Brotodjojo, Dyah Arbiwati</i>	PDF 629-637
<b>A review on Metal-Organic Framework (MOF): Synthesis and Solid Catalyst Applications</b> <i>Mahreni Mahreni, Yuli Ristianingsih</i>	PDF 638-645
<b>Fanaticism Analysis of Social Media Using Machine Learning</b> <i>Agus Sasmito Aribowo, Nur Heri Cahyana</i>	PDF 648-657
<b>Sclerotinia Maceral Analysis to Predict Facies Condition on Coal of Muara Enim Formation, Marapi Area, Lahat, South Sumatera</b> <i>Basuki Rahmad, Sugeng Sugeng, Ediyanto Ediyanto, Sapto Kis Daryono, Gerhana Prasetya Putra, Irwansyah Simatupang, M. Randy Rahman</i>	PDF 656-668
<b>Plastic, Rubber, And Styrofoam Waste Management As Alternative For Green Energy</b> <i>Heru Sigit Purwanto, Bambang Sugiarto, Fauzan Irfandy</i>	PDF 670-676
<b>Development of Spada Wimaya Online Learning Course Based on Moodle During and After the Covid-19 Pandemic</b> <i>Oliver Samuel Simanjuntak, Rifki Indra Perwira</i>	PDF 677-683
<b>Location-Based Employee Attendance Application Development Universitas Pembangunan Nasional "Veteran" Yogyakarta</b> <i>Hidayatullah Himawan, Rifki Indra Perwira, Risyia Ines Putri Siswoyo</i>	PDF 684-693
<b>Integration of the Community Development Program (KKN) Application with the Student Activity and Achievement System (SADEWA) of Universitas Pembangunan Nasional "Veteran" Yogyakarta</b>	PDF 693-703

*Heru Cahya Rustamaji, Simon Pulung Nugroho, Yolanda Putri Aqillasari*

**Utilization Of Coconut Waste As A Planting Media "Cocopeat Plus" In Kebonrejo Village, Candimulyo District, Magelang Regency**

*Dyah Arbiwati, Mofit Eko Poerwanto, Ali Hasyim Al Rosyid*

PDF  
704-710

**Addition Of Metarhizium Anisopliae In Organic Fertilizer For Enhancing White Grub's Control**

*Mofit Eko Poerwanto, Chimayatus Solichah, Danar Wicaksono*

PDF  
711-715

**Geology Information for Community-Based Landslide Risk Prevention and Mitigation**

*Eko Teguh Paripurno, Nandra Eko Nugroho, Aditya Pandu Wicaksono, Awang Hendrianto Pratomo, Septyan Teguh Mahendra*

PDF  
716-720

**Optimization Of Fish Catching Resulting Using Appropriate Technology**

*Sabihaini Sabihaini, Awang Hendrianto Pratomo, Heru Cahya Rustamaji*

PDF  
721-729

**Core Sampling Procedure For Use As Artificial Core In Enhanced Oil Recovery (EOR) Study**

*Bambang Bintarto, Boni Swadesi, Edgie Yuda Kaesti*

PDF  
730-736

**The Effect of Flow Rate Discharge on TDS, pH, TSS, and Cu in Electrocoagulation with Continuous Reactors**

*Rr Dina Asrifah, Titi Tiara Anastasia, Mia Fitri Aurilia, Vindy Fadia Utama, Dian Wulandari, Praditya Anggi Widhiananto, Bagas Yusanto Wibowo*

PDF  
737-746

**Description Processing Of Criminal Cases Using Latent Semantic Analysis Method**

*Hidayatullah Himawan, Dessyanto Boedi Prasetyo, Wilis Kaswidjanti*

PDF  
747-754

**Yields Components Of Some Sweet Corn Line (Zea Mays Var. Saccharata Sturt) Generation S-4**

*Bambang Supriyanta, Dwi Lestari, Danar Wicaksono, Andiko Suryo Putrotomo*

PDF  
755-760

**Trade-Off Value Precision Analysis On Ideal Solution Value In Distance Based Multi Criteria Decision-Making Techniques**

*Sutrisno Sutrisno, Dyah Rachmawati L*

PDF  
761-770

**Hidrogeologi Study of Sand Mine In Merapi Area**

*Tedy Agung Cahyadi, Rika Ernawati, Genadi Nainggolan, Ilham Firmansyah*

PDF  
771-783

**Utilization of Reservoir Proxy Model for Development Strategy Optimization of Combined Steam Flooding & Cyclic Steam Stimulation for Enhanced Heavy Oil Recovery**

*Boni Swadesi, Suranto Suranto, Indah Widiyaningsih, Aditya Kurniawan, Ratna Widiyaningsih, Agung Budiarto, Martrida Jani*

PDF  
784-791

**The Hydrothermal Breccias Characteristics of The Tumpangpitu Porphyry Cu-Au-High Sulphidation Epithermal Au Prospect, Banyuwangi, East Java, Indonesia**

*Sutarto Sutarto, Sutanto Sutanto, Cicih L, Hidayat P, Khafarel L P, Rigenaji P, Kenny L*

PDF  
792-803

**Reservoir Simulation Modeling With Polymer Injection in Naturally Fractured Carbonate Reservoir**

*Mia Ferian Helmy, Indah Widiyaningsih, Edgie Yuda Kaesti, Atma Budi Arta*

PDF  
804-814

**Application of The Analytic Hierarchy Process (AHP) to Analyze Industries Risk Management in Metal Casting Industries**

*Sadi Sadi, Zuhrohtun Zuhrohtun, Indra Kusumawardhani*

PDF  
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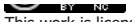
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## **A New Method In The AHP-Weighting Of Criteria For Supplier Selection**

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### **Abstract**

*In the coming years, researchers in the supplier selection are more likely to use a combination of methods of multi-criteria decision making (MCDM). One method of MCDM which often used in such combinations is Analytic Hierarchy Process (AHP). The function of AHP in the combination of MCDM is as the weighting in each criterion. In the AHP weighting, it has a very important problem. The problem is difficult to obtain consistent results when the amount of matrix is relatively large. This study proposes a new methodology to solve the problem. The results of this study indicate that the proposed method is able to fix the inconsistent matrix data of wise pair comparison to be consistent.*

Keywords: Analytic Hierarchy Process, criteria, consistency index, multi-criteria decision making

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## **I. INTRODUCTION**

In the AHP weighting, it has a very important problem. However, human judgments against intangible objects are more likely to be inconsistent (Saaty, 2003). Human judgment is more sensitive and responsive to the growing number of disorders (Saaty, 2003). This condition would make such judgments become inconsistent. If the disorder is the criterion, then too many criteria will approach the more difficult to be consistent. The problem is difficult to obtain consistent results when the amount of matrix is relatively large (i.e., 7 to 9 elements) (Saaty and Kearns, 1985). Each study has a different way of tackling this problem.

There are some studies that the above-mentioned split the criteria into two groups, so it will be expected that each group of criteria is less than seven criteria. These studies are Yang and Chen (2006), Pramanik *et al.* (2017), Haldar *et al.* (2012), Viswanadham and Samvedi (2013), and Freeman and Chen (2015). Yang and Chen (2006) divide into two criteria, namely the qualitative and quantitative criteria. Meanwhile, Freeman and Chen (2015), Haldar *et al.* (2012), and Pramanik *et al.* (2017) used the name of objective criteria and subjective criteria. All studies used the AHP to calculate the weight of subjective criteria. Freeman and Chen (2015) utilized entropy to determine

the weight of the objective criteria. Then, using the average of the two weights (weights of the AHP and entropy) to acquire global weighting. Pramanik *et al.* (2017) and Haldar *et al.* (2012) measured the weight of the objective criteria with normalization techniques. Global. Viswanadham and Samvedi (2013) divided the criteria into two types, namely risk criteria and performance criteria. They applied fuzzy AHP to get supplier ranking using performance criteria. The downside of this research group is no guarantee if each group of criteria has less than seven criteria. The other difficulty is how the merger of the two weights of each of these groups.

There are many studies in the selection of suppliers using a combination of AHP with another MCDM (see Table 1), where they form a set of criteria into one multilevel model, so there are main criteria and sub-criteria. These studies are Sevkli *et al.* (2007), Ramanathan (2007), Wang *et al.* (2009), Kasirian *et al.* (2010), Yucenur *et al.* (2011), Zhang *et al.* (2012), Bruno *et al.* (2012), Azadnia *et al.* (2012), and Yadav and Sharma (2015). In each group of sub-criteria, weights are calculated. This weight is called the local weight. The main criterion in the first level also calculated its weight. Global weights are obtained by combining all the weights at each level. Ranking of the suppliers obtained by calculating the total score based on global significance. (Sevkli *et al.* (2007); Ramanathan (2007); Wang *et al.* (2009); Zhang *et al.* (2012), Yadav and Sharma (2015)), The Technique for Order Preference by Similarity to the Ideal Solution (TOPSIS) (Azadnia *et al.* (2012)) and Analytical Network Process (ANP) (Kasirian *et al.* (2010), Yucenur *et al.* (2011), Bruno *et al.* (2012)). The weakness of this research group is lengthy calculations to obtain global weighting if the level and criteria are too much. In addition, there is no guarantee that if the major criteria or sub-criteria in each major criterion are less than seven.

In the other studies of supplier selection using a combination of AHP with another MCDM, i.e., Pitchipoo *et al.* (2012; 2013<sup>a</sup>; 2013<sup>b</sup>) and Falsini *et al.* (2012), used a methodology that explicitly measures the consistency ratio. However, validation of their model used real industrial examples in which the number of criteria in supplier selection is less than seven. So, the consistency ratio of the measurement results is always less than 0.01. If the number of criteria used is greater than seven, then to get consistent results or valid must be done repeatedly. This will make the models considered less efficient. There is also research that is not described in the methodology of measuring the consistency ratio of the weight of AHP in a combination of AHP with another MCDM to select a supplier. These studies are Zolfani *et al.* (2012), Ertay *et al.* (2011), Ghorbani *et al.* (2013), Chen and Yang (2011), Junior *et al.* (2014), Li *et al.* (2012), and Polat (2016). There is a possibility that these studies (except Polat (2016)) assume not need the consistency ratio if AHP combined with fuzzy logic. However, this logic is not true before they prove the scientific evidence of their hypothesis. Even Polat (2016) ignores the need for a consistency ratio. Part of the discussion in this study will discuss case studies of Polat (2016). Based on the existing weaknesses in the research of supplier selection using AHP combined with other MCDM, this study proposes a new methodology to solve the problem.

## II. RESEARCH METHODOLOGY

The proposed framework for problem-solving is to make the number of criteria is less than seven. The hope is that the results obtained are always consistent, so do not require repetition in data retrieval if obtained inconsistent results. Therefore, longer computation time can be avoided. This proposed method uses a geometric mean to merge two or more criteria. After going through the stages of AHP, the separation of criteria combination can be done using disaggregation techniques.

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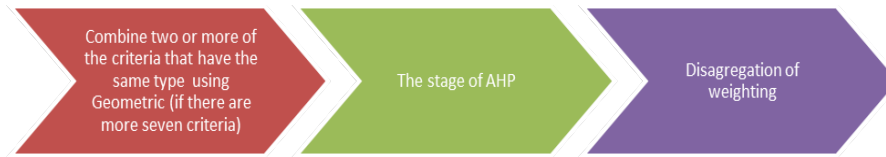


Figure 1. Stage of the proposed method

The steps of the proposed method (see Figure 1) can be explained as follows:

Stage 1: Reducing the number of criteria by combining the criteria have the same type using the geometric mean (Hruska *et al.*, 2014).

$$C_k = \sqrt[n]{C_{ij}C_{jk} \dots C_{yz}} \tag{1}$$

$C_k$  = combination of pairwise comparison from some criteria.

$C_{ij}$  = pairwise comparison of criteria  $i$  and criteria  $j$ , where  $i < j$ .

$N$  = number of comparison of criteria  $i$  and criteria  $j$ , where  $i < j$ .

Stage 2: Giving weight values through the AHP process.

Stage 3: Determining the final weights for each criterion before combined using disaggregation.

$$W_i = C_k p_i n = C_k \left[ \frac{\sum_{l=1}^m c_{li}}{\sum_{i=1}^n \sum_{l=1}^m c_{li}} \right] n \tag{2}$$

$C_k$  = combination of pairwise comparison from some criteria.

$P_j$  = weight proportion of criteria  $i$ .

$N$  = number of comparison of criteria  $i$  and criteria  $j$ , where  $i < j$ .

$C_{li}$  = pairwise comparison of criteria and criteria  $i$ .

Table 1. Resume of both examples

No	Parameter	Hruska <i>et al.</i> (2014) (matrix size: 10x10)	Polat (2016) (matrix size: 11x11)
1	$\lambda_{\max}$	12.475	10.865
2	Consistency index (CI)	0.275	0.0135
3	Consistency ratio (CR)	0.185	0.009

### III. FINDING AND DISCUSSION

In the process of discussion, we will use the case of the selection of suppliers in the two articles, which have a number of criteria for more than seven. Both articles are Hruska *et al.* (2014) and Polat (2016). Both of these examples will be tested for consistency ratio using AHP stages. The results of both can be seen in Table 2.

Table 2. Revised pair-wise comparison matrix case 1

Kriteria	Price (C1)	Quality (C2)	Service and payment terms (C3)	Transport and Delivery (C4)	Willingness of hold stocks by supplier (C5)	Financial, audit, and prospectus (C6)
Price (C1)	1,00	3,00	5,48	5,00	7,00	6,84
Quality (C2)	0,33	1,00	5,48	5,00	7,00	6,84
Service and payment terms (C3)	0,18	0,18	1,00	1,00	5,00	5,52
Transport and Delivery (C4)	0,20	0,20	1,00	1,00	4,00	4,72
Willingness of hold stocks by supplier (C5)	0,14	0,14	0,20	0,25	1,00	1,34
Financial, audit, and prospectus (C6)	0,15	0,15	0,18	0,21	0,75	1,00
Total	2,00	4,67	13,34	12,46	24,75	26,25

In the first example, the criteria of payment terms are one of the company's service, so that these criteria are combined with service criteria. Delivery time is determined by the transportation factor, so the transportation criteria can be combined with the delivery time criteria. At the same time, the company's prospects may be determined by how well the financial condition, and financial factors that can either be seen from how to audit. Therefore, the audit criteria, financial, and prospects of the company can be used as one criterion. By using the average geometry, then the pairwise comparison matrix, which is revised for the first example, can be seen in Table 3.

Table 3. Revised pair-wise comparison matrix case 2

Kriteria	Price (C1)	Financial (C2)	Facilities (C3)	Experience (C4)	Quality (C5)	Safety (C6)
Price (C1)	1,00	1,26	2,08	2,57	1,65	1,59
Financial (C2)	0,79	1,00	1,54	2,25	1,44	1,26
Facilities (C3)	0,48	0,65	1,00	1,58	0,92	0,80
Experience (C4)	0,39	0,44	0,63	1,00	0,96	0,94
Quality (C5)	0,61	0,69	1,09	1,04	1,00	0,87
Safety (C6)	0,63	0,79	1,25	1,06	1,15	1,00
Total	3,90	4,84	7,58	9,50	7,12	6,46

In the second example, the number of pavers criteria, the criteria of the number of road rollers, and the criteria of the number of trucks combined into facility criteria. While the criteria of a number of on-going projects, the criteria of a number of completed projects, and a number of key personnel combined with the company's experience criteria. So, the pairwise comparison matrix for the second

example, which is revised, can be seen in Table 4. The result of the consistency of these two examples can be seen in Table 5.

Table 4. Conclusion of the result of the proposed method

No	Parameter	Hruska <i>et al.</i> (2014) (matrix size: 10x10)	Polat (2016) (matrix size: 11x11)
1	$\lambda_{max}$	6.545	6.043
2	Consistency index (CI)	0.109	0.009
3	Consistency ratio (CR)	0.009	0.007
4	Conclusion	consistent	Consistent

To determine the extent of performance of the proposed method, then used two comparators, i.e., global weighting method and split method. The composition of the hierarchy in the first and second examples can be made into two levels. The first level is performance criteria and risk criteria (Viswanadham and Samvedi, 2013). Performance criteria consist of criteria of price, quality, and lead-time (Viswanadham and Samvedi, 2013). In the first example, lead-time may be replaced with delivery time. In the second example, lead-time may be replaced with a number of on-going and completed projects. All remaining criteria were included in the second level at the foot of the main criteria of risk. To find out more about local and global weight calculations using AHP at many levels (first method) can be seen in Saaty and Shang (2011).

Table 5. Conclusion of the result of the hierarchical method

No	Parameter	Hruska <i>et al.</i> (2014) (matrix size: 10x10)		Polat (2016) (matrix size: 11x11)	
		Perform criteria	Risk criteria	Perform criteria	Risk criteria
1	$\lambda_{max}$	3.138	9.055	3.888	7.014
2	Consistency index (CI)	0.069	0.343	0.890	0.002
3	Consistency ratio (CR)	0.133	0.254	0.042	0.002
4	Conclusion	inconsistent	Inconsistent	Consistent	consistent

Based on the split method of Yang and Chen (2006), the quantitative criteria are price, quality, the term of payment, delivery time, and transport (in the first example). Other criteria are included in the category of qualitative. While, in the second example, all included in the category of quantitative criteria. The results of the first example, which are processed using the split method of Yang and Chen (2006), can be seen in Table 6. Subjective-criteria, in the first example, consists of a willingness to hold stocks by suppliers, prospects of supplier development, service, and auditing of suppliers. But, there is no this type of criteria, in example 2 because there is no successor. All criteria in example 2, are quantitative criteria. Thus, all criteria will be processed using entropy (Freeman and Chen, 2015) and normative (Haldar *et al.*, 2012; Pramanik *et al.*, 2017). The results of their method to solve the first examples can be seen in Table 7.



Table 6. Conclusion of the result of the split method using case 1

No	Parameter	Yang and Chen (2006)		Freeman and Chen (2015)	Haldar <i>et al.</i> (2012) & Pramanik <i>et al.</i> (2017)	
		Quant. criteria	Qualitative criteria	Subjective criteria	Quant. criteria	Qualitative criteria
1	$\lambda_{max}$	6.709	4.548	4.548	6.709	4.548
2	Consistency index (CI)	0.142	0.195	0.195	0.142	0.195
3	Consistency ratio (CR)	0.095	0.219	0.219	0.095	0.219
4	Conclusion	const.	Intact.	Intact.	Const.	Intact.

From the results in Table 4, it can be concluded that the proposed method is able to fix the inconsistent matrix data to be consistent. It was unable to do the hierarchical and split method (see Table 5 and Table 6). In addition, the proposed method also maintains consistency matrix data that have previously been consistent. A comparison of the results of the weight of the proposed method with other methods can be seen in Table 7 (from Example 1) and Table 8 (from Example 2). The ranking of the criteria is based on the value of its weight also can be seen in both Tables 7 and 8. It can be seen that by using the data inconsistent matrix will generate a different sequence of criteria using different methods. Whereas from Table 8, it can be seen that using different methods for data matrix that consistently generate a sequence of criteria which are largely the same. In fact, the proposed method produces the exact same sequence as Freeman and Chen (2015).

Tabel 7. Comparison of the results of the weight for case 1

No	Criteria	Yang and Chen (2006)	Freeman and Chen (2015)	Haldar <i>et al.</i> (2012) & Pramanik <i>et al.</i> (2017)	Proposed method
1	Bid price (C1)	0,165	0,111	0,165	0,1602
2	Financial (C2)	0,135	0,107	0,135	0,1299
3	Personel (C3)	0,111	0,103	0,111	0,1144
4	Pavers (C4)	0,092	0,097	0,092	0,0880
5	Road rollers (C5)	0,080	0,090	0,080	0,0826
6	Trucks (C6)	0,078	0,089	0,078	0,0822
7	Completed project (C7)	0,052	0,068	0,052	0,0455
8	On-going project (C8)	0,059	0,075	0,059	0,0655
9	Quality (C9)	0,076	0,096	0,076	0,0861
10	Incident (C10)	0,104	0,100	0,104	0,0956
11	Experience (C11)	0,048	0,062	0,048	0,0500
	Sum	1,000	1,000	1,000	1,000

Tabel 8. Comparison of the results of the weight for case 2

No	Criteria	Yang and Chen (2006)	Freeman and Chen (2015)	Haldar et al. (2012) & Pramanik et al. (2017)	Proposed method
1	Price (C1)	0,2052	0,1044	0,2052	0,3224
2	Quality (C2)	0,1429	0,0998	0,1429	0,2242
3	Payment (C3)	0,0531	0,0818	0,0531	0,1090
4	Delivery (C4)	0,0495	0,0851	0,0495	0,1104
5	Willingness (C5)	0,0623	0,0623	0,0623	0,0295
6	Financial (C6)	0,0151	0,0484	0,0151	0,0339
7	Prospect (C7)	0,1350	0,1350	0,1350	0,0335
8	Service (C8)	0,2549	0,2549	0,2549	0,0712
9	Transport (C9)	0,0342	0,0805	0,0342	0,0547
10	Audit (C10)	0,0478	0,0478	0,0478	0,0113
	Sum	1,000	1,000	1,000	1,000

#### IV. CONCLUSION AND FURTHER RESEARCH

The proposed method is able to fix the inconsistent matrix data to be consistent. It was unable to do the other method. The proposed method maintains the consistency of matrix data that has previously been consistent.

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