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Assessment and determination of potential sustainable biomass waste using the analytic network process method

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Abstract. A global problem which has not been yet resolved is the volume of waste as a side effect of various activities whose numbers continue to increase. At present waste management becomes a challenge which is being faced by developing countries therefore starting from the selection of raw materials has been carried out an optimal sorting process for efficiency. This study aimed to assess and compare potential biomass waste as an alternative to sustainable waste efficiency. The study used the Analytic Network Process (ANP) method by making pairwise comparisons inter-criteria and inter-alternatives in assessing to obtain the weight of each criterion and alternative. The results showed a pairwise comparison value of cluster goal of potential sustainable biomass waste with the cluster availability of waste sources criteria having the highest priority weighting of 0.43017, compared to other clusters criteria. In the cluster alternatives, three biomass wastes with the highest priority weight were orange peel of 0.27376, pineapple leaf of 0.17764, and sugar palm peel of 0.15488, which were potential as sustainable biomass waste to be developed into various products biomass based such as for renewable heterogeneous catalysts, innovative craft products and various other high value-added products.

Keyword: Analytic network process (ANP), Pineapple leaf, Sugar palm peel, Orange peel, Craf

1. Introduction

Most human activities produce residual waste, which is generated from the industrial, agribusiness and agro-industry sectors as the population increases [1]. Waste is unused material which has a negative impact on causing risks to health, environmental impacts and even social impacts on the community if not managed properly [2]. The problem of solid waste management is the biggest challenge for authorities in both small and large cities in developing countries. This is mainly due to the increase in solid waste generation and the burden on the city budget. In addition to high costs, solid waste management is associated with a lack of understanding of various factors which affect the overall handling system [3]. Recently, in encouraging efforts to increase the efficiency of sustainable waste, minimization of the production of waste from raw resources is carried out by installing facilities to convert solid waste into energy in the municipality [4].

Multi-criteria analysis is a decision-making method that compares alternatives using several criteria simultaneously under complex conditions [5]. The criteria considered in decision making often have links to each other, so the Analytic Network Process (ANP) method can be used to model problems with the linkages between criteria [6]. ANP is a comprehensive decision making technique which is able to combine all relevant criteria in which there are several relationships to get to a decision [7]. In the selection of alternative waste management and assessment of biomass sources, the ANP method has been widely used by researchers [8-11].

In connection with the selection of alternatives which consider various criteria, it is expected to support a city's waste management system. There fore, assessing and comparing potential biomass waste as an alternative to sustainable waste efficiency were the objectives of this research.

2. Experimental Procedure

2.1. Identification of criteria and alternatives in the network model

At this stage, the determination of criteria and alternatives was based on the potential policy of biomass as an alternative energy source which was adjusted to the conditions on the ground. Furthermore, a network model image consisting of clusters and nodes in the cluster was created using Super Decision Software version 2.2. as it could be seen in figure 1. In this study, the network model consisted of three clusters namely cluster goals, cluster criteria and cluster alternative with one node in the cluster goals, five nodes in the cluster criteria and eight nodes in the cluster alternative. Furthermore, each cluster and node in the cluster was connected to find out the overall effect of each node which would then be assessed by judgment on the network model questionnaire Analytic Network Process (ANP) method. table 1.

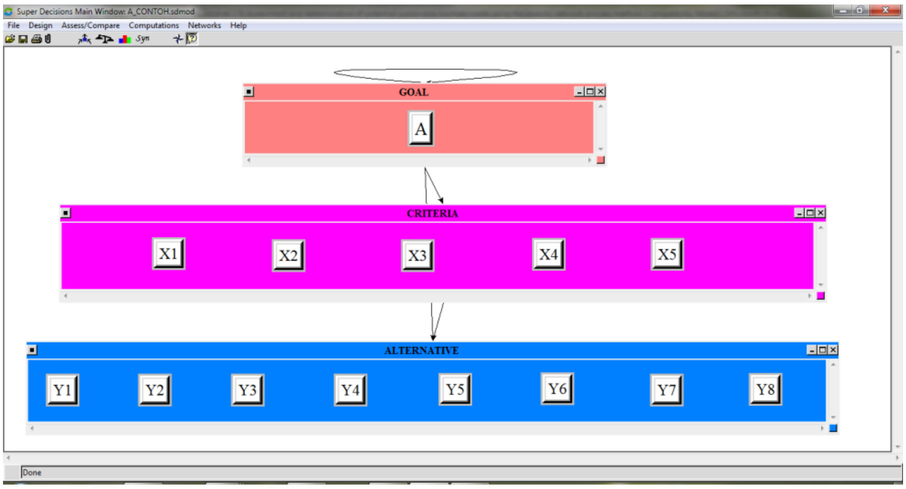


Figure 1: Network model using Super Decision software version 2.2.

In the questionnaire on the potential for sustainable biomass waste using the Analytic Network Process (ANP) method, judgment respondents were chosen that consisted of 6 people representing the government and 4 people representing the community. The pairwise comparison assessment scale 1-9 used in the network model is presented in table 1.

Level of Importance	Definition	Explanation
1	Both important	Both elements have the same effect
3	A little more important	Assessment is less in favor of one element than its partner
5	More important	Assessment is more in favor of one element than its partner
7	Very important	One element is very influential and its dominance is evident
9	Absolutely very important	Evidence that one element is more important than the partner at the highest level of confidence
2,4,6,8	The middle value between the judgments above	This value is given if there is doubt between the two adjacent judgments
The inverse	aij = 1/aij (if for activity i gets one number compared to activity j, then j has the inverse value compared to i).	

Source : [12]

Table 1: The pairwise comparison assessment scale.

2.2. Determinantion of criteria and alternative weights in the network model

Weighting was carried out on all linkages inter clusters and inter nodes having more than one linkage from the network model questionnaire having been assessed. Previously, the intensity of respondent's importance was determined for each linkage of the network model questionnaire conducted using Ms. Excel 2007 software. The Analytic Network Process (ANP) generalizes a pairwise comparison process to assess each component by including priority criteria and alternatives [13]. Then the data were processed using the Super Decision software version 2.2 with stages, namely:

1) The weighting used a pairwise comparison method between two elements with 9 (nine) scales so that all the elements were included. Comparison of cluster goals and cluster criteria as it could be seen in figure 2.

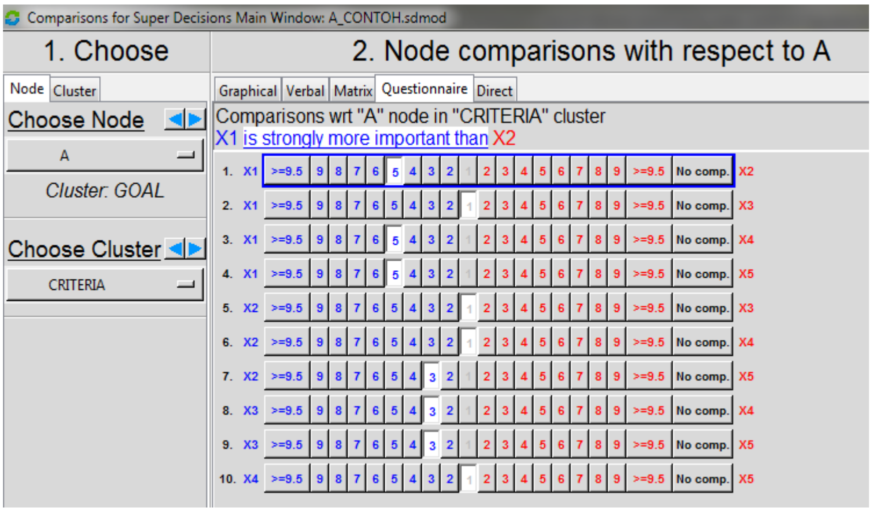


Figure 2. Comparison of cluster goals and cluster criteria.

2) Calculation of the weight of the relationship between nodes and clusters measured from the consistency value of the pairwise comparison results. Results could be accepted if the value of consistency ratio (CR) $\leq$ 0.1. If the CR value> 0.1 then it was necessary to make improvements in filling out the questionnaire.

3) Next, the cluster matrix was obtained the priority weighting results from the weighting of the links among nodes are arranged on a matrix that corresponds to the cell (unweighted super matrix).
4) Then the weighted super matrix stage is performed, which the value of it was obtained by multiplying the cluster matrix cell value with the value of each unweighted super matrix cell.
5) After obtaining a weighted super matrix, the next step was to find a limiting matrix to get a stable priority value. The final result of the calculation would give priority weighting of all elements and components contained in the normalized weighting by priority cluster.

3. Results and Discussion

3.1. Criteria and alternatives for assessment of potential sustainable biomass waste

The criteria used in assessing the potential for sustainable biomass waste in this study were the availability of waste sources, waste characteristics, production process technology, government regulations and sources of capital (economy) based on observations, secondary data collection and interviews with relevant stakeholders. Furthermore, alternatives in the assessment consist of cigarette stub, plastic, styrofoam, pineapple leaf, orange peel, sugar palm peel, oil palm empty fruit bunches and palm kernel shell based on the potential policy of biomass as an alternative energy source. Network model for assessing the potential for sustainable biomass waste could be seen in figure 3.

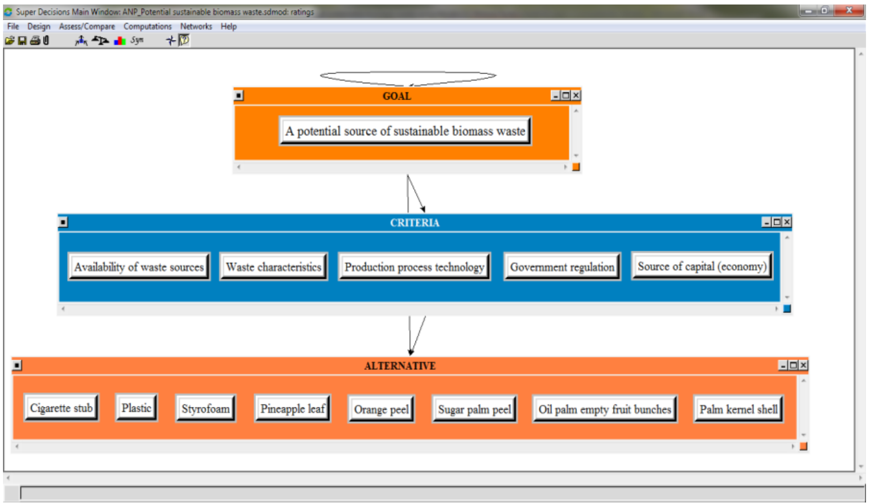


Figure 3: Sustainable biomass waste potential assessment network.

Figure 3 showed the interdependence relationship between criteria and alternatives which influence decision making. Based on the results, there was an inner dependence relationship occurring in nodes in a cluster affecting other nodes in the same cluster, including the waste characteristics criteria which were 8affected by availability of waste sources criteria. The availability of waste sources criteria was affected by production process technology criteria, government regulation criteria which were affected by capital sources (economy) criteria and capital sources (economy) criteria affected by production process technology criteria. Beside the inner dependence relationship, in the network model there was also an outer dependence relationship which occured in nodes in other clusters, including availability of waste sources criteria, waste characteristics criteria, production process technology criteria, government regulation criteria and capital sources (economy) criteria affected by nodes in alternatives biomass waste.

In assessing and selecting an optimal biomass energy source in the State of Iran using the Analytic Network Process (ANP) to make efficient policies in the Iranian power generation industry. Based on the criteria and sub-criteria collected from experienced experts in the Iran Renewable Energy Organization (SUNA) there was an inner dependence and outer dependence relationship in the biomass source network model which was most preferred for producing fuel needed for power generation [11].

3.2. Weighting of criteria and alternatives in assessment of potential sustainable biomass waste

The assessment of potential sustainable biomass waste was carried out by weighting criteria and alternatives. Pairwise comparisons were used to obtain local priorities of the elements in one cluster seen from the main cluster [12]. The importance value of pairwise comparisons was then entered into the input data processed using the Super Decision Software version 2.2. as it could be seen in figure 4. Respondents were considered consistent if the value of consistency ratio (CR) was less than equal to 0.1 (≤ 0.1).

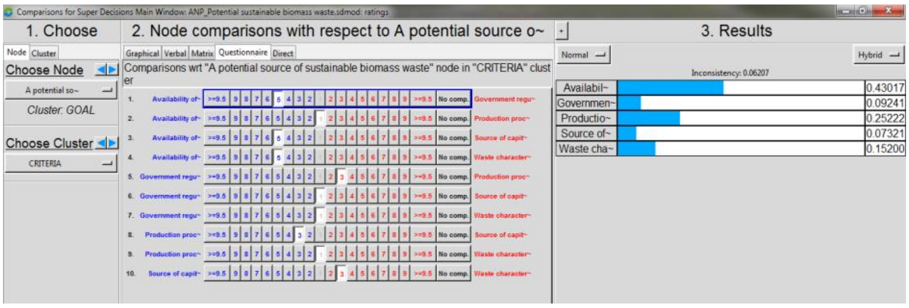


Figure 4: Comparison of cluster goals and nodes in the cluster criteria.

The next step was assessing the pairwise comparison of cluster criteria and cluster alternatives as it could be seen in figure 5.

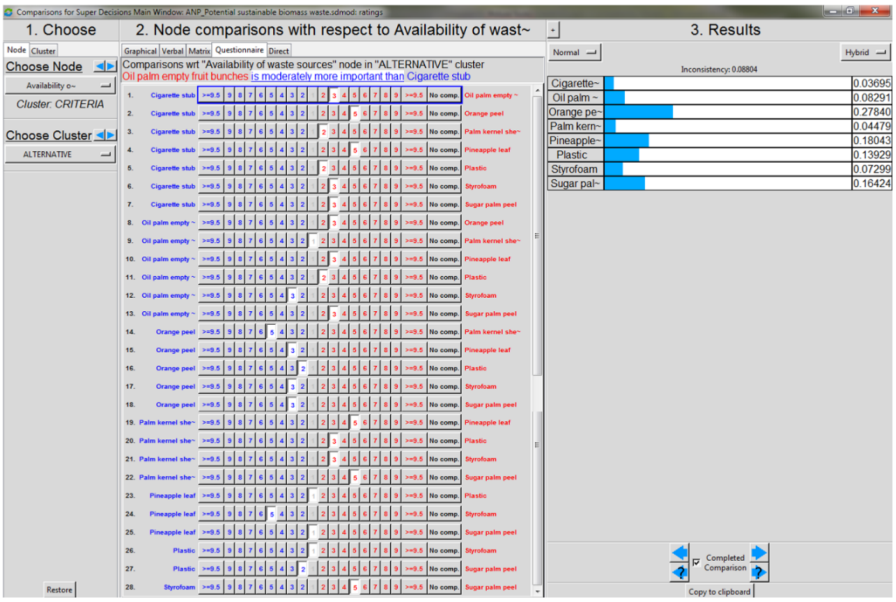


Figure 5: Comparison of nodes in the cluster criteria and nodes in the cluster alternatives.

Then proceed with an assessment of the pairwise comparison of cluster goals and cluster alternatives as it could be seen in figure 6.

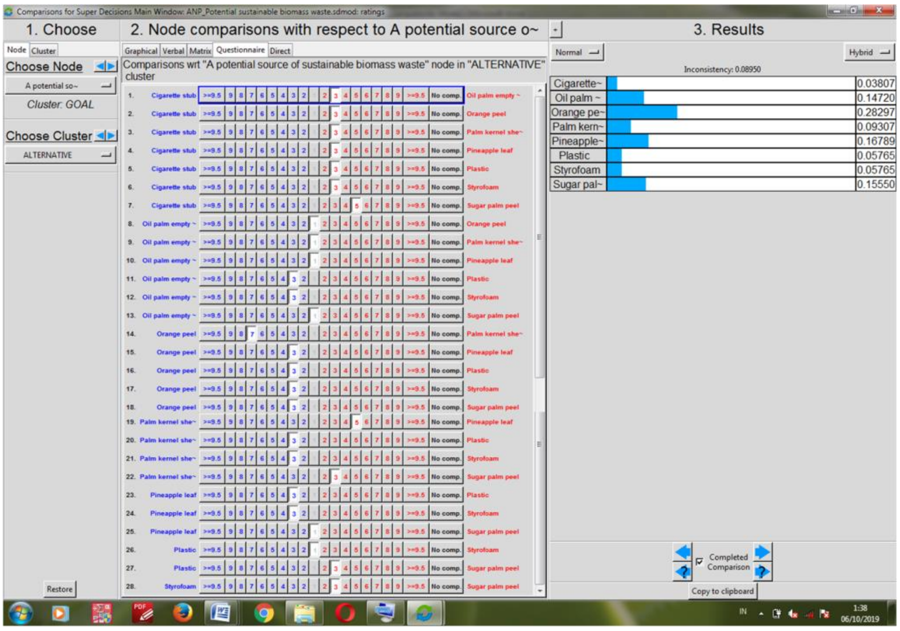
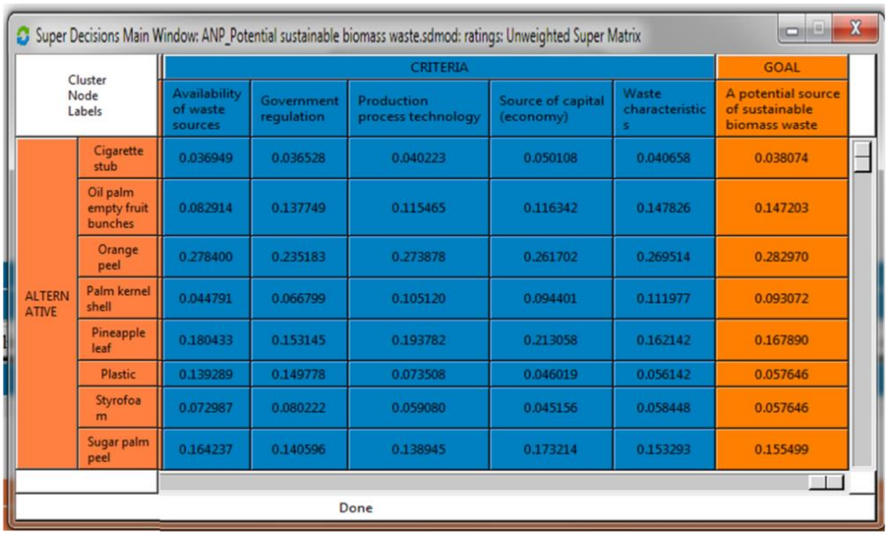


Figure 6: Comparison of cluster goals and nodes in cluster alternatives.

Based on the pairwise comparison of the cluster goals and the nodes in the cluster criteria, a consistency ratio (CR) of 0.06207 (6.207%) was obtained, the pairwise comparison among nodes in the cluster criteria and the nodes in the cluster alternatives obtained a CR value of 0.081634 (8.1634%) and comparison of cluster goals and nodes in cluster alternatives obtained a CR value of 0.08950 (8.95%). This showed that the respondents were consistent in assessing the pairwise comparisons because CR ≤ 0.1 and was within the inconsistency ratio (≤10%).

The results of data processing Analytic Network Process (ANP) using Super Decisions software version 2.2. for unweighted supermatrix weights could be seen in figure 7 and weighted supermatrix weights could be seen in figure 8.

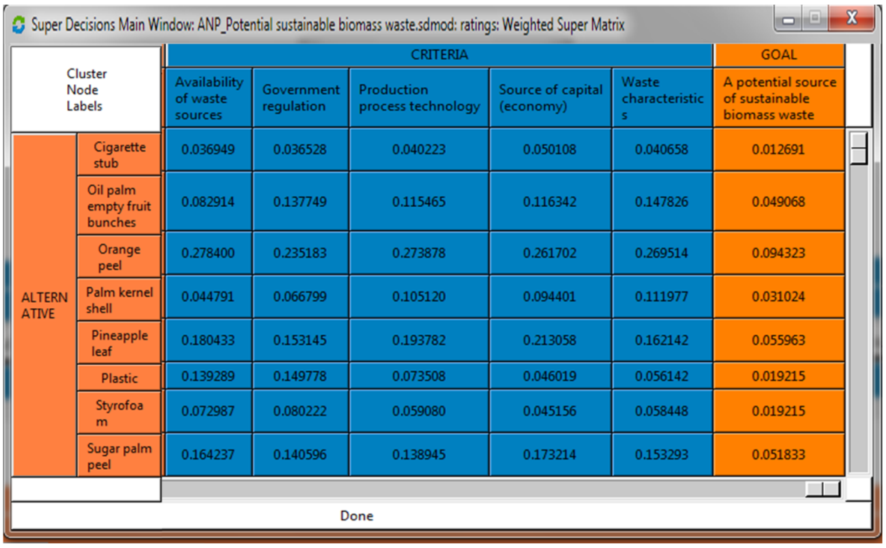


Super Decisions Main Window: ANP_Potential sustainable biomass waste.sdmod: ratings: Unweighted Super Matrix

Cluster Node Labels		CRITERIA: Availability of waste sources	CRITERIA: Government regulation	CRITERIA: Production process technology	CRITERIA: Source of capital (economy)	CRITERIA: Waste characteristics	GOAL: A potential source of sustainable biomass waste
ALTERNATIVE	Cigarette stub	0.036949	0.036528	0.040223	0.050108	0.040658	0.038074
	Oil palm empty fruit bunches	0.082914	0.137749	0.115465	0.116342	0.147826	0.147203
	Orange peel	0.278400	0.235183	0.273878	0.261702	0.269514	0.282970
	Palm kernel shell	0.044791	0.066799	0.105120	0.094401	0.111977	0.093072
	Pineapple leaf	0.180433	0.153145	0.193782	0.213058	0.162142	0.167890
	Plastic	0.139289	0.149778	0.073508	0.046019	0.056142	0.057646
	Styrofoam	0.072987	0.080222	0.059080	0.045156	0.058448	0.057646
	Sugar palm peel	0.164237	0.140596	0.138945	0.173214	0.153293	0.155499

Done

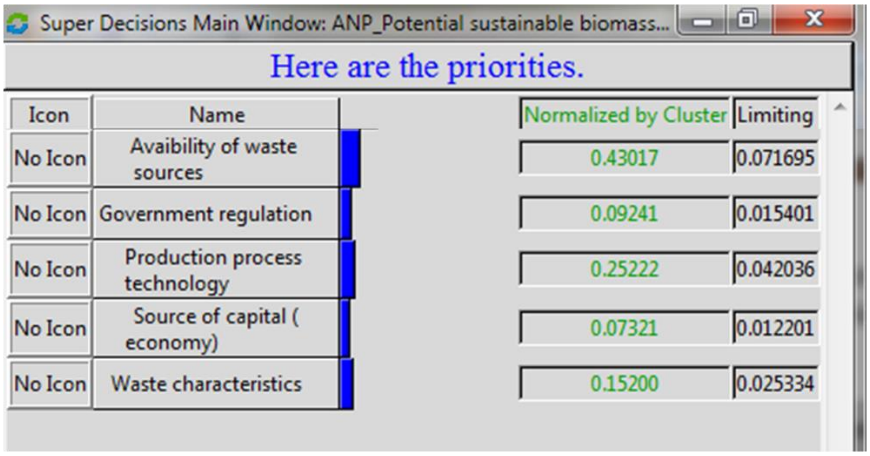
Figure 7: Weight of the unweighted supermatrix.



Cluster Node Labels		CRITERIA: Availability of waste sources	CRITERIA: Government regulation	CRITERIA: Production process technology	CRITERIA: Source of capital (economy)	CRITERIA: Waste characteristics	GOAL: A potential source of sustainable biomass waste
ALTERNATIVE	Cigarette stub	0.036949	0.036528	0.040223	0.050108	0.040658	0.012691
	Oil palm empty fruit bunches	0.082914	0.137749	0.115465	0.116342	0.147826	0.049068
	Orange peel	0.278400	0.235183	0.273878	0.261702	0.269514	0.094323
	Palm kernel shell	0.044791	0.066799	0.105120	0.094401	0.111977	0.031024
	Pineapple leaf	0.180433	0.153145	0.193782	0.213058	0.162142	0.055963
	Plastic	0.139289	0.149778	0.073508	0.046019	0.056142	0.019215
	Styrofoam	0.072987	0.080222	0.059080	0.045156	0.058448	0.019215
	Sugar palm peel	0.164237	0.140596	0.138945	0.173214	0.153293	0.051833

Figure 8: Weight of the weighted supermatrix.

Furthermore, the priority weight of the cluster criteria in the assessment of the potential for sustainable biomass waste using Super Decisions software version 2.2. could be seen in figure 9.



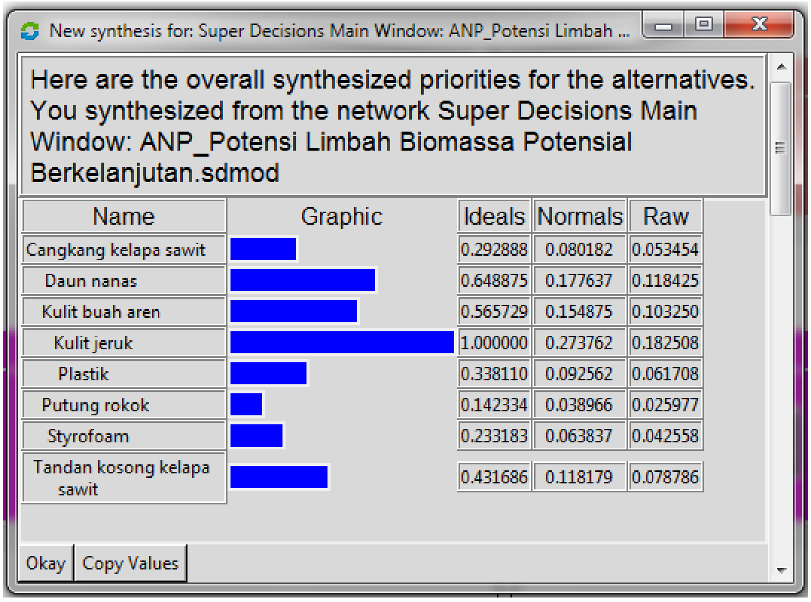
Icon	Name	Normalized by Cluster	Limiting
No Icon	Avaibility of waste sources	0.43017	0.071695
No Icon	Government regulation	0.09241	0.015401
No Icon	Production process technology	0.25222	0.042036
No Icon	Source of capital (economy)	0.07321	0.012201
No Icon	Waste characteristics	0.15200	0.025334

Figure 9: The priority weight of the cluster criteria in the assessment of the potential for sustainable biomass waste.

Based on the results of weights of normalized cluster, the order of the highest priority weight criteria was the availability of waste sources criteria of 0.43017. This showed the availability of waste sources criteria was the most important criterion among the others because of the presence of waste which often encountered in daily life such as agricultural waste, industrial waste, and waste in a landfill. Furthermore, it was followed by the production process technology criteria of 0.25222, waste characteristic criteria of 0.15200, government regulation criteria of 0.09241 and the lowest weight in the source of capital (economic) criteria of 0.07321.

The current use of waste as a renewable raw material was the most interesting and efficient in its use. Availability of waste based on general potential was seen from the level of raw waste which had not been used, for technical potential it was seen from the condition of economic raw materials collected in one place with a distance of <30 km and seen from the optimization potential. There fore it was known that waste raw material had been utilized but not yet efficient because the system utilization was still low, for example the use of bagasse as fuel for power plants [14, 15]. The availabilities of biomass sources which could be produced into biogas with the main raw materials were agricultural and forestrial waste, livestock waste, municipal biodegradable waste, and municipal and industrial wastewater. In addition, they were supported by appropriate infrastructure in the utilization of biomass sources for producing alternative fuels [11].

To determine alternative priority weights in determination of the potential for sustainable biomass waste, synthesis was carried out using the Super Decisions software version 2.2. as it could be seen in figure 10.


New synthesis for: Super Decisions Main Window: ANP_Potensi Limbah ...

Here are the overall synthesized priorities for the alternatives. You synthesized from the network Super Decisions Main Window: ANP_Potensi Limbah Biomassa Potensial Berkelanjutan.sdmod

Name	Graphic	Ideals	Normals	Raw
Cangkang kelapa sawit		0.292888	0.080182	0.053454
Daun nanas		0.648875	0.177637	0.118425
Kulit buah aren		0.565729	0.154875	0.103250
Kulit jeruk		1.000000	0.273762	0.182508
Plastik		0.338110	0.092562	0.061708
Putung rokok		0.142334	0.038966	0.025977
Styrofoam		0.233183	0.063837	0.042558
Tandan kosong kelapa sawit		0.431686	0.118179	0.078786

Okay Copy Values

Figure 10: Ranking of alternative priorities in determination of the potential for sustainable biomass waste

Based on figure 10, there were three alternatives having the highest priority weighting in determination of the potential for sustainable biomass waste. They were orange peel of 0.27376, pineapple leaf of 0.17764 and sugar palm peel of 0.15488. Orange peel had the highest priority because all of its criteria got the highest rating of any other waste, followed by pineapple leaf and sugar palm peel. This showed that the weighting of the criteria obtained could affect the results of alternative priorities in determination of the potential for sustainable biomass waste. A large criteria weight would significantly influence the priority results of the assessment and determination. Alternative biomass waste made from orange peel, pineapple leaf and sugar palm peel because it could be applied as a renewable material as biomass energy with biomass-to-fuel conversion technology. Government support and commitment were needed to create energy (biomass) security which was managed independently by the community.

The use of biomass conversion technology could be divided into three, namely direct combustion in dry biomass waste, thermochemical conversion with thermal treatment to trigger chemical reactions in producing fuel, and biochemical conversion using microbial assistance in producing fuel. The potential biomass energy products were biobriquette, pyrolysis and catalyst in the production process of biodiesel additives [11, 16, 17]. In addition, the use of waste or residue still requires structuring and organizing until it could have economic and social scale which was meaningful to the community with proper management for the development of biomass energy when fossil energy was no longer a mainstay [18].

4. Conclusion

Based on the conducted results in this study, it could be concluded that:

1. The network model for assessing and determining the potential for sustainable biomass waste shows the interdependence relationships between criteria and alternatives which influence decision making. The relationship between the criteria, which becomes the main consideration, is the relationship in the criteria (inner dependence), namely the availability of waste sources to the characteristics of waste and the relationship of criteria in the alternative (outer dependence), namely biomass waste to the availability of waste sources.
2. Pairwise comparison value criteria for availability of waste sources has the highest priority weighting of 0.43017 compared to other cluster criteria.
3. In the cluster alternatives, three biomass wastes with the highest priority weight are orange peel of 0.27376, pineapple leaf of 0.17764, and sugar palm peel at 0.15488 which have the potential as sustainable biomass waste to be developed into biomass energy products.

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