APPLICATION ANALYTIC HIERARCHY PROCESS (AHP): A CASE STUDY OF E-WASTE MANAGEMENT IN SURABAYA, INDONESIA

Dino Rimantho[1], Bambang Cahyadi[2], Denny Dermawan[3]

[1,2]Industrial Engineering Department, Pancasila University, Jakarta Indonesia
[3]Waste Water Treatment Departement, Surabaya Shipbuilding State Polytechnic, Surabaya, Indonesia
Rimantho.dino@gmail.com[1], bamca81@yahoo.com[2], dennydermawan@yahoo.com[3]

ABSTRACT

Increasing the quantity of e-waste is a concern to all stakeholders in most countries in the globe. The paper explains the method of Analytic Hierarchy Process (AHP) is applied with Expert Choice software to choose some variables that influence the management of electronic waste in the city of Surabaya. There are five variables contained in the management of electronic waste such as: Technology, Financial, Environmental, Social and Methods. Questionnaires carried out to select the five variables. Replication and questionnaire design was modified from the World Bank and UNEP. Questionnaires were distributed to five key informants located in the city of Surabaya. The result using Expert Choice software shows the values of the preference variables electronics waste management in the city of Surabaya i.e. Technology = 0.095, Financial = 0.251, = 0.455 Environmental, Social = 0.154, Method = 0.046. The judgments were found to be consistent, precise and justifiable with narrow marginal inconsistency values. This paper also provides a thorough sensitivity analysis to express the confidence in the drawn conclusions.

Keywords: *E-waste, AHP, expert choice, sensitive analysis, Surabaya*

1. INTRODUCTION

Currently in most countries, the management of the increase in quantity of e-waste is a most important attention. Studies conducted by Wath et al., (2010) classifies the main problem of e-waste management into two sections, namely the increase in the number of e-waste and environmentally friendly disposal. The analog equipment disposal to landfills discovery triggered the emergence of new technologies rapidly. As a consequence, the potential for environmental degradation comes from the disposal of e-waste activities.

The electronic equipments become quickly obsolete for nearly 20 years, triggered by the emergence of a new design, technology with smart functions periodically. Various factors that lead to a decreased life span of electronic items such as advances in electronic technology, design and marketing consumer (Kidde et al., 2013). For example, a study conducted by Widmer et al., (2005) found that the average age of a new computer decreases, thus causing the increase in volume of computer disposal and export to developing countries. Furthermore, Oteng-Ababio (2012) underlines that the increase in the number of electronic products discarded due to the lifetime of the product has been shortened.

Electronic waste has different descriptions according to the researchers. In general, Oteng-Ababio (Oteng-Ababio, 2012, p. 152) highlighted the definition of electronic waste as the end of life electrical and electronic equipment. Similarly, Electronic waste is often referred to as a result of technology that used by the community who do not use the back because it has been removed and has reached the end of life electronics (Rode, 2012). This encourages the researchers who provide a major concern due to the massive growth of the waste stream as well as the presence of some toxic heavy metals in electronic waste, such as esters of lead, cadmium, mercury, polybrominated diphenyl (Wong et al., 2007; Hidy et al., 2011).

Some developing countries are working to respond to concerns over electronic waste. Some of the factors that concern the country such as building waste and proper recycling and recover the valuable resources to reduce the amount of electronic waste that is disposed. In some developing countries, electronic waste management system has not been established. This is due to the different characteristics of electronic waste with municipal waste. There are many research publications related to electronic waste management and the potential solution to the problem (Yang et al, 2008.; Babu et al., 2007; Hidy et al., 2011).

This study aims to assess the potential of waste electronic devices or products that may be targets for Waste Electrical and Electronic Equipment (WEEE) recycling and management in Surabaya. There is a critical need to identify the rank of electronic waste for recycling mandatory and management in Surabaya. Selection of the proper management of electronic waste can be a challenge to policy makers. This is because in making the right decision and objective procedures and criteria of evaluation is often a lack of information for policy makers and researchers. Therefore, to achieve the expected goals of the management of electronic waste, then decision makers may integrate the quantitative tools in the evaluation procedure. This can identify the management of electronic waste in an efficient and objective in the proper recycling process. In this study, methods of analytical hierarchy process (AHP) are used to rank the criteria and establish an evaluation model of the policy-making process for electronic waste recycling.

The application of AHP has been performed in a number of studies on environmental management. In the United States performed the application of the AHP method in the management of surplus mercury (Randall et al., 2004). A study conducted by Wang et al., (2009) in order to reduce the complexity of the system to choose solid waste management landfill waste sites suitable for use AHP method. In addition, Yue et al., (2010) proposed the method of AHP as the methodology that can be adopted to assess various alternative electronic waste recycling to provide eco-friendly solutions

2. LITERATURE REVIEW

2.1. E-waste management background in Indonesia

The potential risk of impact on the environment and humans is a result of an increase in demand for electronic and electrical equipment, giving rise to the challenge and deemed appropriate method to dispose of end-use electronics products. The development of new technological advances in products accelerates discarded electronic equipment before the end of its life span. As an illustration, the data from the Indonesian Central Bureau of Statistics (BPS) reported that the number of households has landlines and cell phones around 61.84% in 2009 and has increased of about 78.96% in 2011 (BPS, 2012). Moreover, the BPS also reported that about 5:27% of households that have a desktop and laptop / notebook computers in 2009 and have increased by 8.80% in 2011. A study conducted by YLKI, (2012) noted that Indonesia produced about 12,500,000 kg / year and imported television around 6,687,082 kg / year in 2012. Furthermore, the annual consumption of television in Indonesia reached 4.3 million units, while the refrigerator to reach around 2.1 million units and air conditioners and washing machines respectively reached approximately 900,000 units in 2007 (Indrietta, 2009). As a result placed Indonesia as one of the Asian countries that have the largest consumption of household electronics.

Officially, There is no data on the amount of e-waste recycling (both formal and informal sectors nationally) and recycling rate (Andarani and Goto, 2012). However, the authors predicted generation of electronic waste from households in Indonesia in 2015 approximately 16 844 tons/month or around 3.2 million units/month. In addition, a study conducted by Rochman (2010) found in the city of Yogyakarta, producing about 250 metric tonnes of waste every day, with e-waste is expected to grow 1.2 tons (Rochman, 2010). In this study, a set of PC including CRT monitors, motherboards, Central Processing Unit (CPU), Random Access Memory (RAM), an optical disc drive, hard disk, keyboard and mouse.

There are two main sources of e-waste in Indonesia, such as domestic e-waste and disposal of e-waste imported from developed countries. E-domestic waste generated from various sources, for example, household, commercial, electronics manufacturers and retailers, government agencies, secondary markets of old electronic devices. Research conducted by Rochman (2010) found that households sell unused electronic products to informal e-waste traders generally.

Similar with other developing countries such as China and India, Indonesia is also one of the destinations of used electronic delivery from the developed countries. This trade is considered illegal by the Basel Convention on the Control of Trans boundary Movement of Hazardous Wastes and their disposal. The Basel Convention is an international treaty that addresses the uncontrolled disposal of such materials, this agreement applies in 1992 and Indonesia has ratified this agreement in late 2009 (IRIN, 2009). E-waste may be a potential problem for the Indonesian state if not managed properly. Field inspections by the Indonesian Ministry of Environment reported that importation of E-waste occurs with misleading terms in importation documents. Common terms such as "mix metals scrap" or "plastic for recycling" are often used for E-waste as attempts to avoid Indonesian cross-border controls (Krishna 2003; Agustina 2007)

2.2. Application of the Analytic Hierarchy Process (AHP)

AHP is one method that is structured to deal with a complex decision making problem, which consists of many alternatives such as projects, actions and scenarios (Saaty, 1995). AHP is organized according to the hierarchical structure of several combinations of alternatives in decision making. For example, knowledge, experience and intuition. Consequently, this method provides an opportunity for each person to make decisions on various types of problems. For example, planning, priority setting, the selection of the best alternative and the allocation of resources (Garfì et al., 2009).

Tuzmen and Sipahi, (2011) underlines that when there is subjectivity in a problem, the AHP is an effective method of decision making. Further, the authors note that the AHP is also very appropriate to solve the problem where the decision criteria are arranged in a hierarchy into sub-criteria. By using a series of pairwise comparisons of elements of simple decision hierarchy may reduce the complex decisions. Studies conducted by CIFOR, (1999), emphasizes that the synthesis of the results of this comparison is able to provide the best decisions and provide clear reasons for the choices made.

Saaty (1980) developed a number that represents the ratio of the scale and the relative importance of the criteria. The scale used is the value in the range 1 to 9. In order to determine the weight of the selected criteria, the criteria should be compared with others, where the data is displayed in a matrix. Further, Sharma, et al., (2008), noted that the comparison matrix of these factors becomes an important means of calculation. Table 1 Scale value of pairwise comparisons.

Table 1. Pairwise comparison scale (Saaty, 1980)

Intensity of importance	Explanation
1	Two criteria contribute equally to the objective
3	Experience and judgement slightly favour one over another
5	Experience and judgement strongly favour one over another
7	The criterion is strongly favoured and its dominance is demonstrated in practice
9	The importance of one over another affirmed on the highest possible order
2, 4, 6, 8	Used to represent a compromise between the priorities listed above

There are a three-step application of the AHP method in decision making.

Step 1: establish a pairwise comparison matrix of each hierarchy. Implementation of the pairwise comparisons should be made after the making of a hierarchical structure on each indicator of all levels. If no elements are already there, "the pairwise comparisons" should be made to n (n-1) / 2 times. The matrix is used to store the results of pairwise comparisons are wise. To obtain the relative weights between each indicator using eigenvectors as the formula below:

$$A = (a_{ij})_{nxn} = \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & & a_{2n} \\ \vdots & & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{pmatrix} \quad (1)$$

Step 2: compute the maximum eigenvector and eigenvalue.
In this step, each matrix is normalized and be found the relative weights. The relative weights are given by the right eigenvector (w) corresponding to the largest eigenvalue (λ_{max}), as:

$$Aw = \lambda_{max} * w \quad (2)$$

Step 3: consistency test
When eigenvalue doesn't equal n, difference between λ_{max} and can be used as a standard of measuring consistency between expert's opinions, and this process is called a consistency test. Saaty suggests to judge the consistency of the matrix through the consistency index (CI) and consistency ratio (CR). As presented in formulas (4) and (5), consistency of matrix is high when CR is below 0.1. The Consistency Index (CI) can be calculated, using the following formula (3)

$$CI = \frac{\lambda_{max} - n}{n-1} \quad (3)$$

Using the final consistency ratio (CR) can conclude whether the evaluations are sufficiently consistent. The CR is calculated as the ratio of the CI and the random index (RI), as shown in Eq. 4.

$$CR = \frac{CI}{RI} \quad (4)$$

The number 0.1 is the accepted upper limit for CR. If the final consistency ratio exceeds this value, the evaluation procedure has to be repeated to improve consistency (Borajee and Yakchali, 2011).

Table 2. Random Index (Saaty, 1980)

n	1	2	3	4	5	6	7	8	9	10
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

3. METHODOLOGY

The research in this study is a case study on e-waste management in Surabaya city. Data collection was carried out on the value of the factors that affect the management of electronic waste. The questionnaire survey will be conducted with key informants to obtain information about, electronic waste management in Surabaya city. Key informants will be community leaders, government officials, academics, or anyone who has knowledge of and access to information on electronic waste management in Surabaya city. The following aspects will be included in the questionnaire: technology, financial, environmental, social, and methods of managing e-waste management.

The Surabaya city will be classified into five areas according to: high, middle and low income population areas. In each area key informant will be selected as the target interviewee. Determination of population sampling will use simple random sampling strategy. This method will provide the same opportunity for every member of the population to be selected into the sample. To determine the number of key informants will use confidence level 95%, anticipated population proportion 5% and absolute precision 20 percentage points. Thus, the number of key informants is 5 (Lwanga and Lemeshow, 1991). The selection of key informants in each area will be selected based on the information provided by the head of the district administration. If more than two key informants proposed in the areas, one key informant will be selected based on the following criteria: duration of experience with the community, knowledge of the social structure and behaviour, and willingness to participate as key informants in this study. The questionnaire design replicates and modifies procedures followed in other studies of social assessment and public participation in E-waste management by World Bank (Bernstein, 2004) and UNEP (2012). The data collected was processed using Expert Choice program. The expert Choice program is a software that can be used to assist with the calculation method of Analytic Hierarchy Process (AHP). With this software can analyse the sensitivity and printing graphs and table calculations.

4. RESULT AND DISCUSSION

4.1. Structuring of hierarchical trees of options for e-waste management

There are four steps in AHP such as modelling problems, weight assessment, weighted aggregation and sensitivity analysis (Ishizaka (2009). This section will review the four steps used by the AHP is based on a simple problem: a variable to the management of electronic waste. As required in the conventional AHP protocol, that the elements to be grouped into homogeneous groups so it can be significantly and compared with other elements. In addition, each element in one level must be associated with some elements on a higher level. The overall objective of the decision maker is the first level in the structure of the AHP. Furthermore, the factors that contribute to the purpose of the second level. In addition, the alternatives available to the application is a third level. Data processing is performed using Expert Choice according to the questionnaire released in five people are considered to be used as a decision-making information electronic waste management in the city of Surabaya.

Figure 1 shows the hierarchical structure of the problem cases to be observed that the selection of e-waste management is based on the five factors. The lines connecting the boxes is a relationship between the level of need is measured by pairwise comparisons with directions to a higher level. For example, in choosing the management of e-waste, which is more important between technology and financial factors? Which is more important between social factors and the Methods, Technology, Environment and Finance. It will be repeated on each factor.

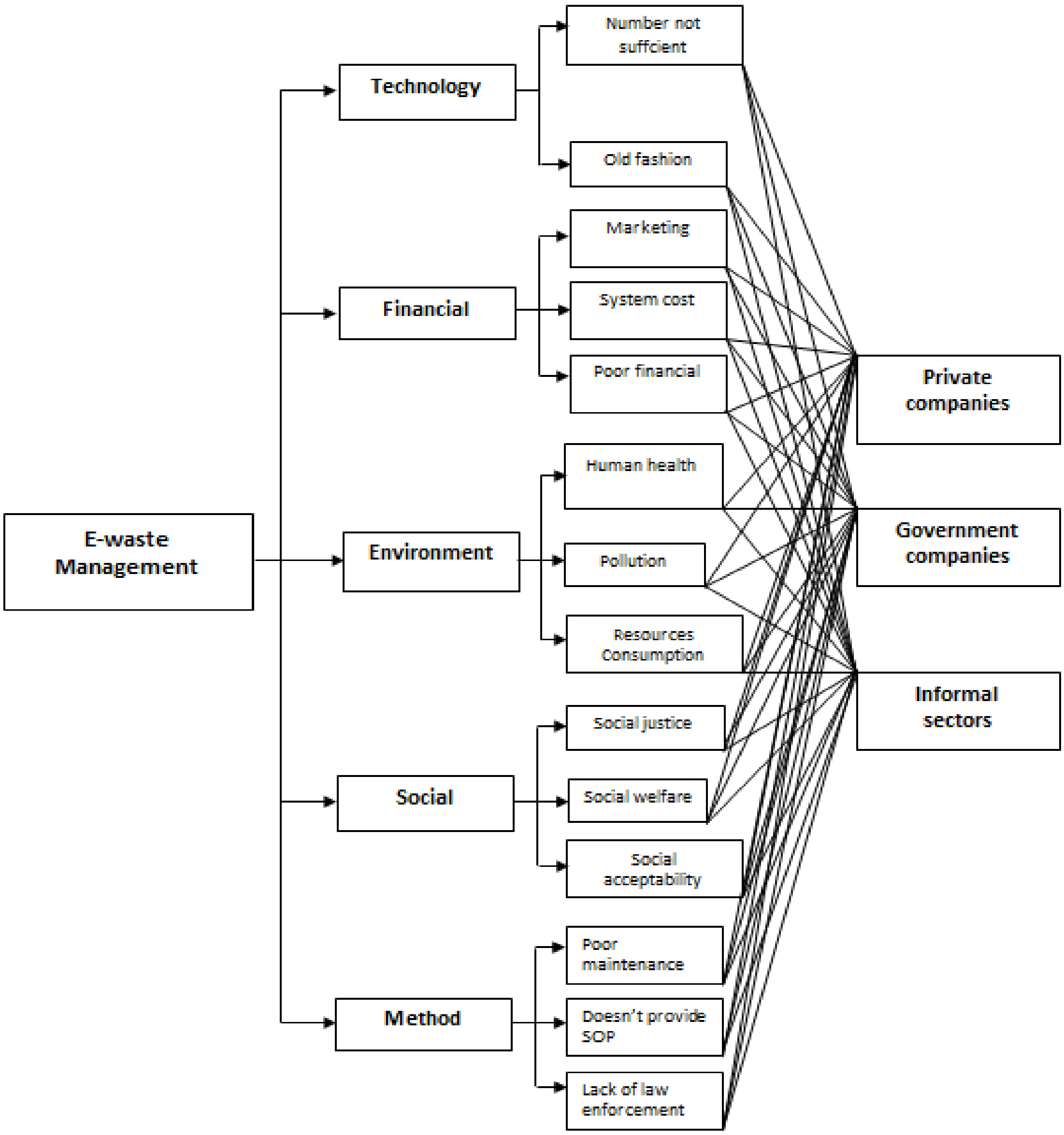

Figure 1. Structuring of hierarchical trees of options for e-waste management

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In decision making, the pairwise comparison matrix will collect from each node hierarchy (e.g. Figure 2). Using the same preference scale of nine levels allows AHP to evaluate the quantitative and qualitative criteria of alternatives. It can scale numerical, verbal and lines.

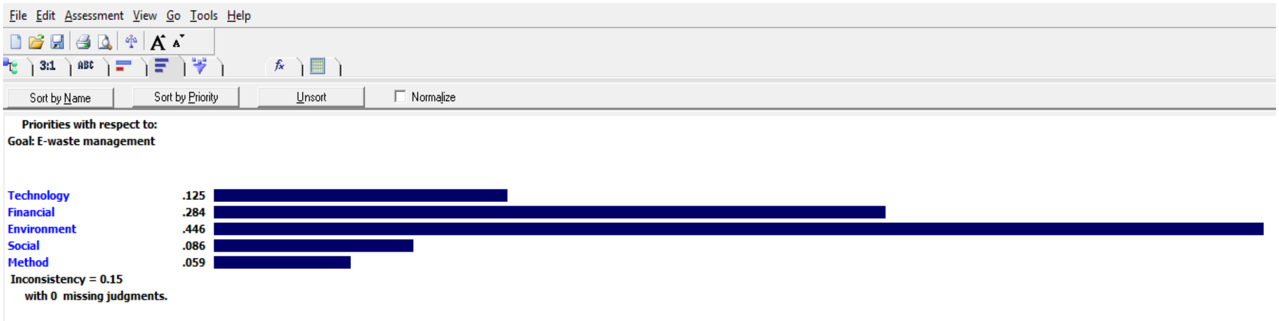

Figure 2. Comparison matrix of the first node

Figure 5 is the result of data processing by using Expert Choice according to the questionnaire that was circulated to 5 people to know the preferences of electronic waste management in the city of Surabaya. As a result known, Environment = 0.446, Technology = 0.125, Finance = 0.284, Social = 0.086 and Methods = 0.059.

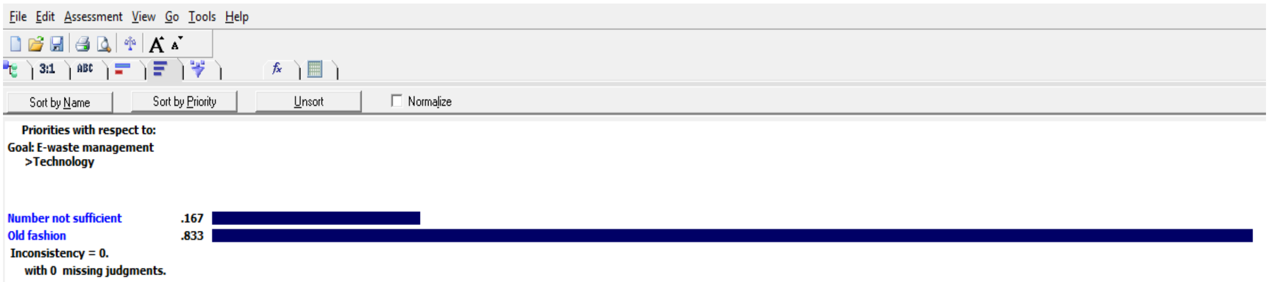

Figure 3. Synthesis with Respect to Goal of Technology

Based on the results of data processing expert respondents obtained that main priority subcriteria old fashion = 0.833 numbers not sufficient and = 0.167. Details of the value of all the alternative results can be seen in Figure 3.

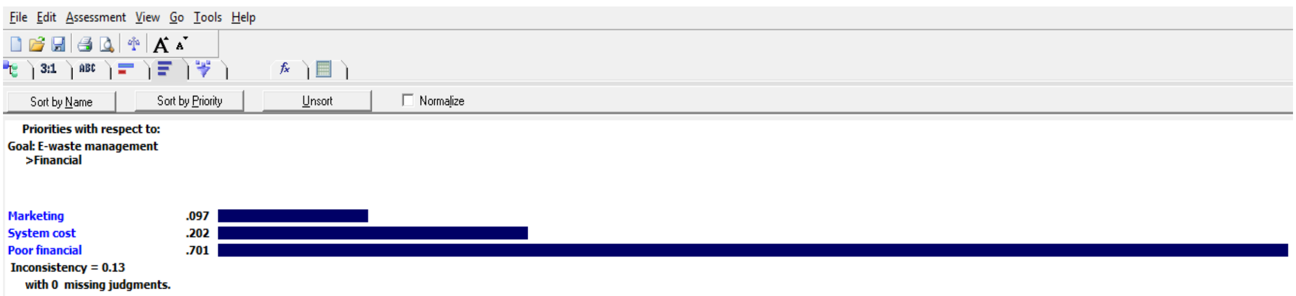

Figure 4. Synthesis with Respect to Goal of Financial

Based on the results of data processing expert respondents obtained that main priority sub criteria poor financial= 0.701, System cost = 0.202 and Marketing = 0.097. Details of the value of all the alternative results can be seen in Figure 4.

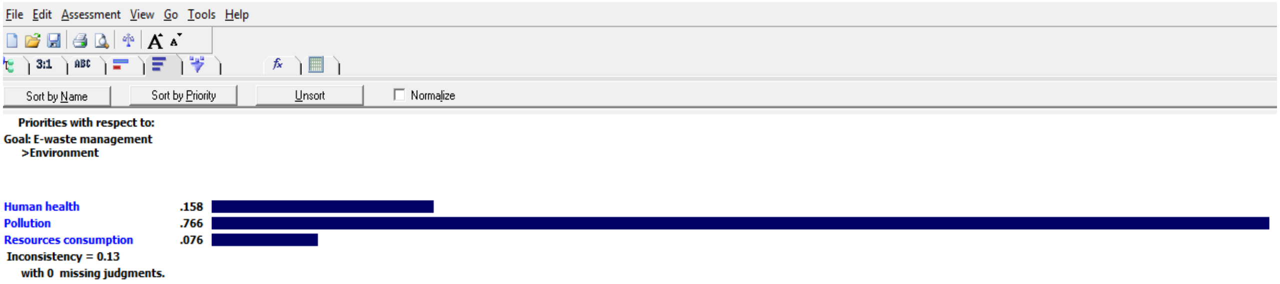

Figure 5. Synthesis with Respect to Goal of Environment

Based on the results of data processing expert respondents obtained that main priority sub criteria Pollution = 0.766, Human health = 0.158 and Resources consumption = 0.076. Details of the value of all the alternative results can be seen in Figure 5.

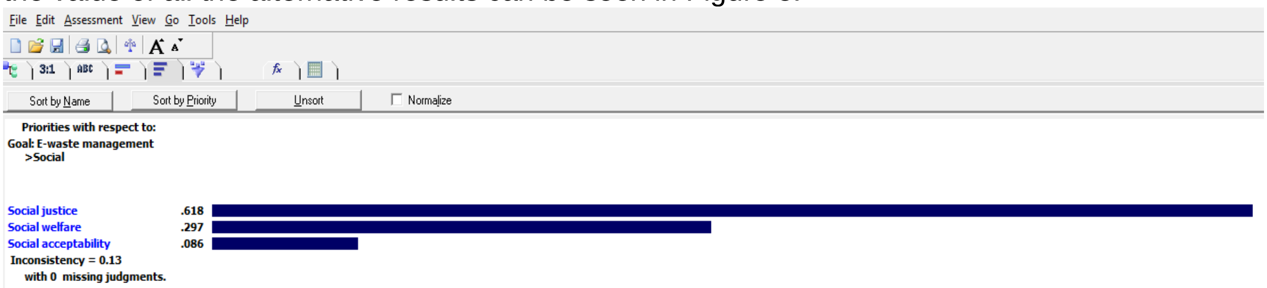

Figure 6. Synthesis with Respect to Goal of Social

Based on the results of data processing expert respondents obtained that main priority sub criteria Social justice = 0.618, Social welfare = 0.297 and Social acceptability = 0.086. Details of the value of all the alternative results can be seen in Figure 6.

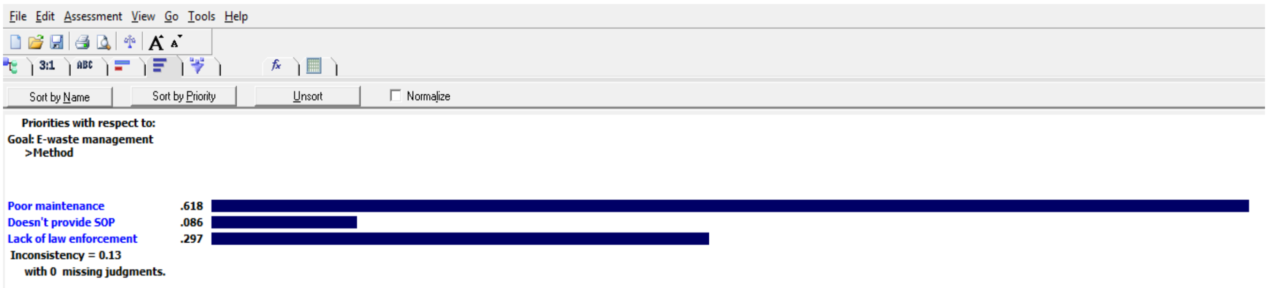

Figure 7. Synthesis with Respect to Goal of Method

Based on the results of data processing expert respondents obtained that main priority sub criteria Poor maintenance = 0.618, Lack of law enforcement = 0.297 and Doesn't provide SOP = 0.086. Details of the value of all the alternative results can be seen in Figure 7.

4.2. Sensitivity Analysis

Sensitivity analysis is the last step of the decision-making process, in which the input data will be modified in order to observe the impact on the results. The results are said to be strong if the rankings have not changed. With an interactive graphical interface can perform sensitivity analysis.

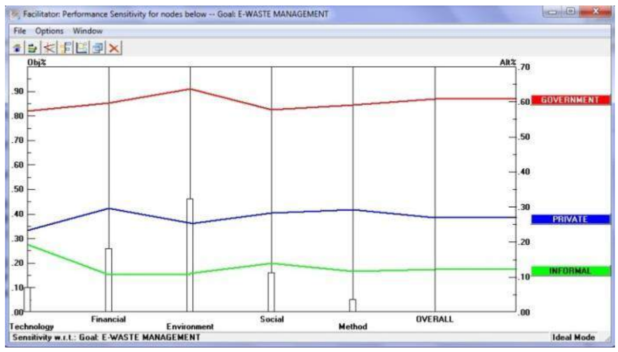

Figure 8. Graphic of Performance Sensitivity

Expert Choice potentially has a different sensitivity analysis, where the figure 8 shows overall government, private sectors and the informal sector has not changed much in all conditions. Furthermore, the illustration above also shows that changes in any factors such as technology, environment, financial, social and methods do not provide significant influence on all stakeholders (government, private sector and the informal sector). For example, If the technology factor improved implementation target of about 80%, there will be a decline in other factors such as environmental factors decreased to about 10%. It is can be concluded that technological factors have an impact on environmental factors if changed. Furthermore, financial factors also impact significantly on the decline and rise of other factors. For example, if there is an increase in the target at approximately 70% of financial factors will reduce damage to the environment around 18%. The sensitivity analysis in Expert Choice varies the weights of the criteria as input data. It is also conceivable to have in the future by performing a sensitivity analysis, interactive variety of other local priorities.

The core theme is one way to determine the effect of input variables on the output variable in the sensitivity analysis. In addition, the sensitivity analysis can also be used to determine the potential influence of small variations in the weights can change the decision. If not, we would be reassured that our choice was reasonable. Graph sensitivity Expert Choice software will be used to test the possibility of a change in decision after making an appraisal of the relative importance of each decision factor. Each different graphics mode of Expert Choice provides a different viewpoint in the sensitivity analysis. The user can easily manipulate the priority criteria and immediately see the impact of the change in the results.

5. CONCLUSION

Management of electronic waste has varying factors and different preferences of each country. This is because every country has its own characteristics of electronic waste management issues. However, almost all countries have in common in terms of sustainable development decision-making related to the management of electronic waste. The variety of preference factor in decision-making can be one of the factors determining the difficulty of a decision. AHP analysis showed that an efficient knowledge-based approach to help measure the expert knowledge to assist in the qualitative analysis of multi-criteria decision making. The results of this study can be used as a starting point for designing a better investigation of the factors determining the preference of decision-making on the management of electronic waste in Indonesia.

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