Jurnal Teknologi

Full Paper

SELECTING THE BEST COMPOSTING TECHNOLOGY USING ANALYTICAL HIERARCHY PROCESS (AHP)

Najah Sofia Md Zaini, Noor Ezlin Ahmad Basri, Shahrom Md Zain, Nur Fatin Mat Saad

Department of Civil and Structural Engineering, Faculty of Engineering & Built Environment, Universiti Kebangsaan Malaysia, 43600 Bangi, Selangor, Malaysia

Article history
Received
25 June 2014
Received in revised form
9 April 2015
Accepted
1 October 2015

*Corresponding author
sofiamz88@gmail.com

Graphical abstract

Abstract

The Analytic Hierarchy Process (AHP) has been used widely to solve multi-criteria selection problem. It is a technique that allows the decision makers to set their priorities and help make the best selection when both tangible and intangible aspects need to be considered. This study uses the AHP to select the best composting technology for the UKM composting centre where the accumulation of organic wastes are generated daily from the cafeteria and landscape activities within the UKM campus. Experts who are familiar and who have some years of experience on solid waste management at UKM were interviewed to do the pair wise comparisons which are structured with four criteria namely environmental, economy, social and technical aspects. These criteria then expanded into a few more sub-criteria. The alternatives for the composting technology are windrow composting and in-vessel composting. The analysis is done using the Super Decisions software. The result shows that technical factor is the most important factor with (0.5000), followed by environmental (0.2517), economy (0.1941) and social (0.0542) factors. The end result shows that windrow composting is the best composting technology according to these four factors with the priority of 0.6236 while composting in—vessel has the priority of 0.3765.

Keywords: Analytic Hierarchy Process, composting technology, organic waste

Abstrak

Proses Analisis Hierarki (AHP) merupakan kaedah yang telah digunakan secara meluas untuk penyelesaian masalah multi kriteria. Teknik ini membenarkan pembuat keputusan meletakkan nilai kepentingan dan membantu pemilihan terbaik apabila kedua-dua aspek boleh dinilai dan tidak boleh dinilai harus dipertimbangkan. Kajian ini menggunakan kaedah AHP untuk menentukan teknologi pengomposan yang terbaik bagi pusat pengomposan UKM di mana sisa organik yang dijana adalah daripada kafeteria dan aktiviti landskap diseluruh UKM. Pakar yang arif dan mempunyai pengalaman dalam pengurusan sisa pepejal di UKM terlibat dalam temu bual perbandingan berpasangan di mana empat kriteria dikenal pasti iaitu persekitaran, ekonomi, sosial dan teknikal. Kriteria ini kemudiannya dikembangkan kepada beberapa sub-kriteria lagi. Alternatif teknologi pengomposan adalah timbunan berbalik dan kompos dalam bekas. Analisis dijalankan menggunakan perisian Super Decisions. Keputusan yang diperoleh menunjukkan aspek teknikal adalah faktor yang paling penting dengan nilai kepentingan 0.5000, diikuti oleh aspek persekitaran (0.2517), aspek ekonomi (0.1941) dan sosial (0.0542). Sintesis akhir menunjukkan pengomposan timbunan berbalik merupakan teknologi terbaik berbanding kaedah kompos dalam bekas dengan nilai kepentingan 0.6236 berbanding 0.3765.

Kata kunci: Proses Analisis Hierarki, teknologi pengomposan, sisa organik

1.0 INTRODUCTION

The National University of Malaysia (UKM) is currently developing a composting centre to provide services to promote an environmentally sustainable campus and also to serve as a platform for further research on composting. To achieve this, the Department of Development and Maintenance UKM (JPP) and Zero Waste Campus Research Group (ZWCG) have collaborated to upgrade the solid waste management in UKM. Several studies have been done on food waste and yard waste composting using both windrow and in—vessel composting techniques. During the period, there are many issues such as the lack of budget and support from the other parties, equipment, infrastructure development, animal attack, odor and others which also serve as the factors that have affected the process. Due to the problem raised during the research, a few factors affecting the composting process are identified. Based on the problem at hand, a study on selecting the best composting technology using decision-making tools is attempted for this research.

The Multi Criteria Decision Making (MCDM) is a technique that demonstrates how the human brain works on decision making with a complex relationship forms among criteria and alternatives [1]. Often when people are making judgment, they tend to consider a number of factors in order to select the best option. Hence, the Analytic Hierarchy Process (AHP) is developed to reflect how humans actually think towards solving problems [2]. In this solid waste management plan, the AHP is used to improve the technology selection by evaluating various criteria [3]. The benefit of using this method is that it requires input data that are easy to obtain because no statistical sample data are needed [4] because people have been struggling, or rather have been unsuccessful in gathering statistical methods from the past and present to make a prediction of the future [5]. Thus, this tool is suitable to be used in composting management plan.

Organic Waste Composting Activity in UKM

Organic wastes at UKM have been divided into two categories which are domestic waste and landscape waste. Domestic waste is waste that comes from the cafeterias, dormitories, faculties, office buildings and other centres (Figure 2a) while landscape waste is the end product of the landscape activity within the campus such as tree trimming, grass cutting, dried leaves collection and others (Figure 2b). UKM has generated approximately 45 % of organic wastes (from domestic waste) [6] and 2.4 ton/day yard wastes [7]. Two types of composting have been used which are in – vessel composting (Figure 3a) and windrow composting (Figure 3b). These two technologies have been used for both food waste and yard waste and the mixture of those two types of organic wastes. At the beginning, a small shed is built at the Rahim Kajai College to 1a), however because of the great amount of yard waste, JPP has appointed a new location spanning approximately 5016 square meters behind the Education Faculty to run the bigger scale of organic waste composting (Figure 1b)

The composting centre has started to operate as the research platform to carry out the organic waste composting process as an alternative to treat the waste. It has the potential to be implemented at UKM at a bigger scale. Currently, the management team at UKM which is JPP has shown the interest to do the composting program as well. Previously, issues like odor [8], support from the workers [9], animal attack and cost [10],and a potential river pollution by leachate has been the obstacles. According to the problem, it is the main concern to expand the criteria and sub-criteria of factors that affect the selection of the best technology using the AHP model.

1 (a) 1(b)

Figure 1 (a) The first attempt using a small shed at the cafeteria and (b) Composting centre behind the Education Faculty, UKM

2(a) 2(b)

Figure 2 Oganic wastes in UKM (a) Landscape waste (b) Food waste

3(a) 3(b)

Figure 3 Composting technique that has been used in UKM; (a) rotary drum (in – vessel technique) (b) the turned windrow

MCDM Tools: Analytic Hierarchy Process (AHP) and Composting at UKM

Initially, the research only focused on the end product quality to compare the best technology based on the EM ratio, organic waste ratio and also the product quality itself. By using the MCDM, an alternative approach was applied where various angles of opinion are gathered from the expertise of the SWM in UKM. Their opinion is very important to solve the problem on selecting the best composting technology based on their knowledge and experiences. Figure 4 shows the connection between the studies that have been done at UKM and the current study using the AHP.

AHP is one of the MCDM techniques that has structured the ways to perform the decision making [5]. It was developed by Thomas L. Saaty based on the mathematics and psychology by using a rational framework that has the purpose of quantifying the elements, to relate all the elements towards the goal intended, and to evaluate the alternative solution [11]. One of the benefits is that the AHP does not need a statistical significant sample size as it can be applied with only a single respondent [2].

There are three basic steps in the AHP proposed by Thomas L. Saaty in 1970's; i) decompose the AHP model, ii) make a comparative judgment by using pair wise comparison iii) synthesis the data or priorities [12]. The first step is done by collecting information from the previous study and empirical experiences [1]&[12]. The second step is to structure the questionnaire of the pairwise comparison where two elements are compared with each other at one time and the weight is assigned by using the Saaty's scale. The elements at the lower lever are compared with respect to the upper level of the AHP model constructed [13]. After that, the synthesis can be done by following the AHP procedure or with the aid of reliable software. Noor Suraya Romali *et al*. (2013) stated that the result from the AHP procedure and software synthesis has small differences in the range of 0.30 % - 4.24 % [14].

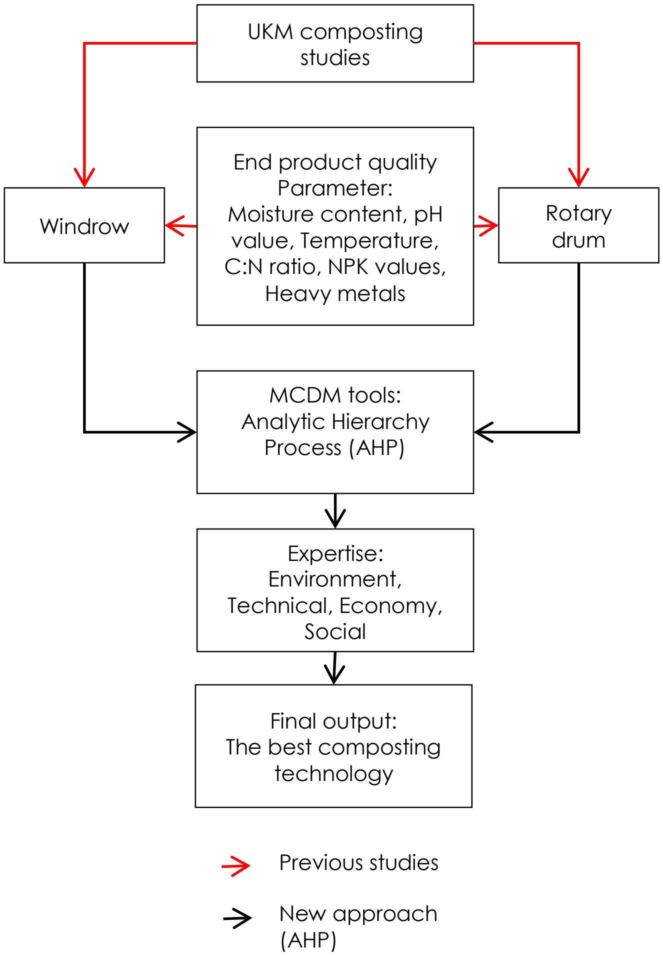

Figure 4 The framework of decision making at UKM

2.0 METHODOLOGY

The methodology for this research is illustrated in Figure 5. This study basically has 3 phases that involve the construction of the AHP model by gathering technical references as journals, handbooks, technical reports and interview sessions with experts, the construction of questionnaire according to the AHP model constructed and data analysis using the Super Decisions software.

Phase 1 : AHP Model Decomposition

The AHP model has four elements which are goal, criteria, sub-criteria and alternatives. To develop the AHP model, information was gathered as many as possible from the literature review (books, journals, theses and others) and a few interviews with experts were also conducted. The criteria chosen are shown in Table 2.

Phase 2 : Pair Wise Comparison

A set of questionnaire is prepared according to the model developed and this is given to the expert. They have to give weight to one of the elements, according to which is more important than the other elements using the Saaty's scale. The criteria and sub-criteria are compared to each other by two elements at one time. It is because the human brain can make the best judgment over two elements [1] (Please refer to the Table 1). Then, the priorities are calculated mathematically using a matrix.

Phase 3 : Data Analysis

The analysis of data is done using the Super Decision software. The AHP is constructed in the software and the synthesis is carried out to rank the composting technology according to its priority.

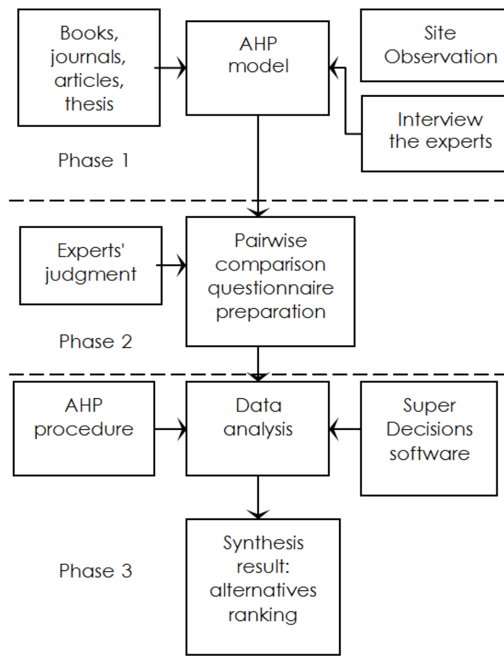

Figure 5 Research methodology flow chart illustrating ways of performing the AHP procedure

SUPER DECISIONS Software

For this study, the Super Decisions software which is easy to use, is adopted in order to construct the AHP model and compute the result from simple to complex connection. This software was developed by William Adams and his team in 1999 – 2003 and funded by Creative Decisions Foundation, 4922 Ellsworth Avenue, Pittsburgh, PA 15213, USA [2]. Hence, it is suitable for both the AHP and ANP methods.

Table 1 The Saaty's scale proposed by Thomas L. Saaty in 1970's

Intensity of important	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgment slightly favor one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgment strongly favor one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance is demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation

3.0 RESULT AND DISCUSSION

The outcome from phase 1 is the AHP model for the research that is shown in Figure 6. The top level is to select the best composting technology, the second level constitutes the criteria which are environmental, economy, social and technical, while the third level is the sub-criteria which consist of odor, pathogen, water pollution caused by leachate, water source, capital cost, operational cost, end product marketing, top management, labor, machine, maintenance and time to complete the composting process. The bottom level is the alternative treatment methods which are windrow composting and in – vessel composting methods. These methods are used for this study as UKM has successfully adopted these techniques. Table 2 is the description of the criteria and the sub-criteria for this model. The pairwise comparison questionnaire is built according to the connection of each element

Analysis of the AHP Model

Figure 7 shows the AHP model constructed in the Super Decisions software. Different colors are used to differentiate each level. From the pairwise comparison, the data are then keyed in in the Super Decisions Software. The priority of each sub-criterion is shown in Table 3. It shows that the technical aspect is the most important factor, and for each factor, water pollution caused by leachate, capital cost, labor and time to complete the process is important compared to the other factors. Capital cost and operational cost are important because these are the main costs of the overall process [7].

The overall synthesis shows that windrow composting is higher than the in-vessel composting with the priority of 0.6236 than 0.3765, respectively. Table 4 shows the overall synthesis result

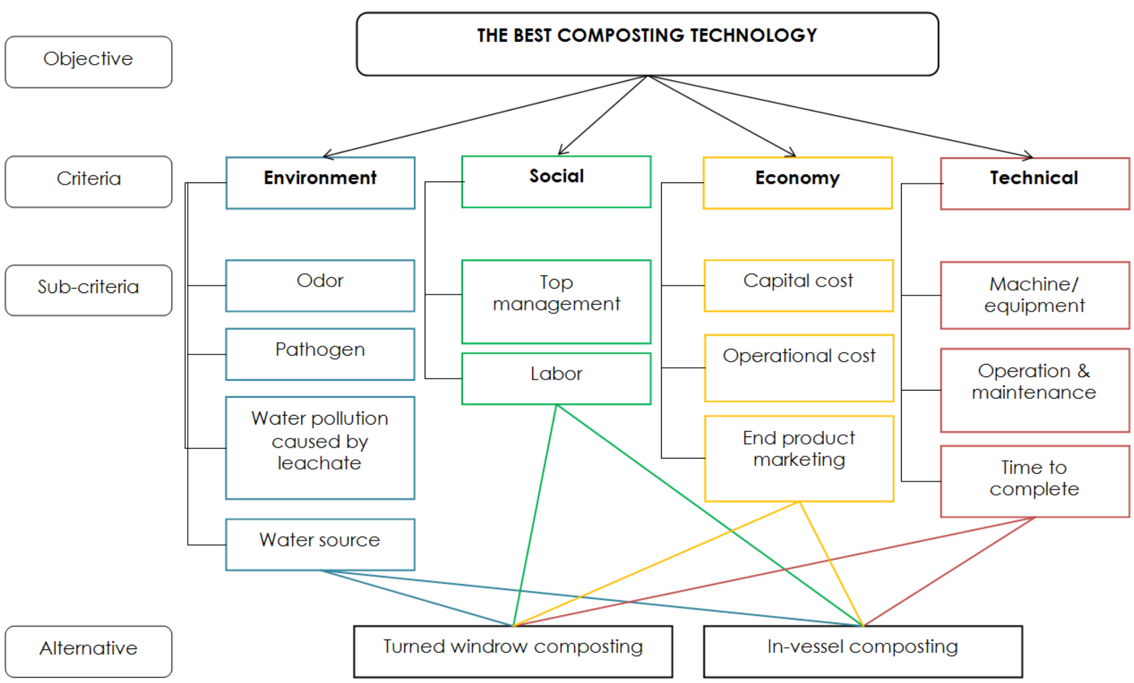

Figure 6 The AHP model

Table 2 The criteria's description for the AHP model

Criteria	Label	Sub-Criteria	Description
Environment	EO	Odor	Bad odor can cause uncomfortable condition and attract vector
	EP	Pathogen	Pathogen is very easy to grow inside the organic wastes if the composting process is not properly managed
	EPL	Water pollution caused by leachate	Leachate can harm the river located near the composting centre
	EW	Water for composting process	The location of the centre is quite far from the water sources, and the weather is also very hot
Economy	ECC	Capital cost	Capital cost is needed to develop the centre to start the process
	EOC	Operation cost	Operational cost is needed during the composting process
	EEM	Marketing of product compost	The end product can give many benefits in terms of the environment and also to bring profit
Social	ST	Top management	Management group who is responsible for the solid waste management at UKM
	SL	Labor	The workers to do the composting process on site
Technical	TME	Machine/equipment	Machine/equipment that is easy to use and operate
	TM	Maintenance	Maintenance of the machine, equipment, or even the site condition
	TT	Time to complete the composting process	Shorter period to complete the process is better, where it can reduce larger volume of waste in shorter time

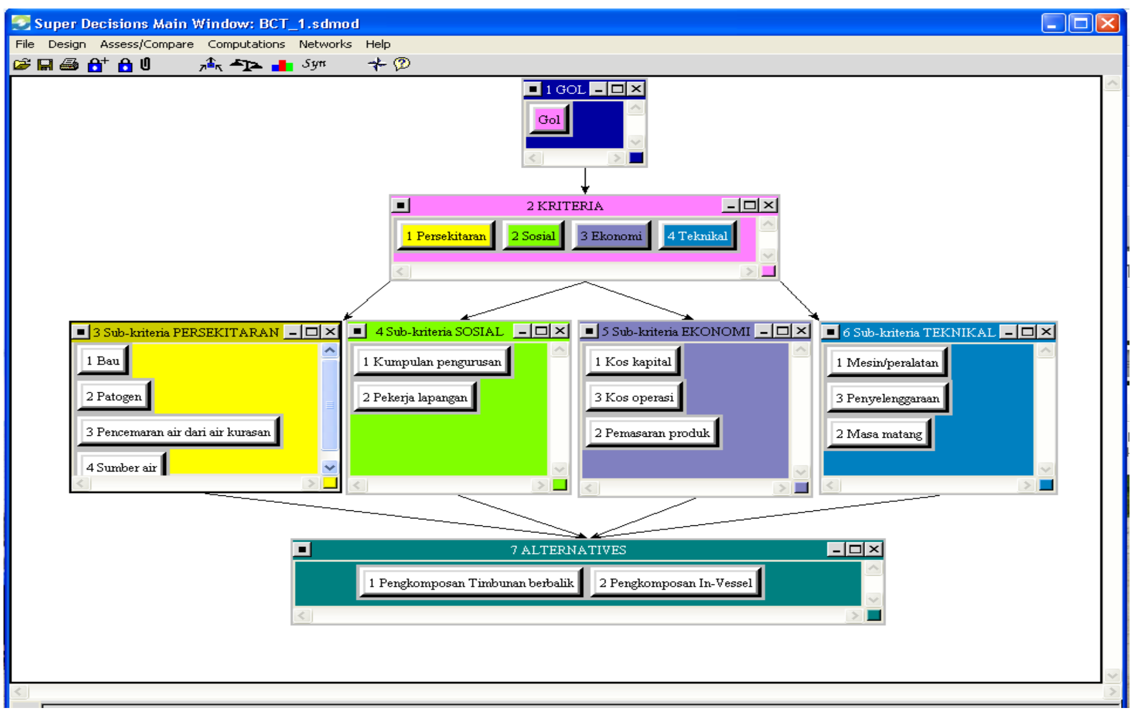

Figure 7 The AHP model in the super decisions software

Nowadays, the in-vessel composting is much more likely to be implemented as the end product that can be made ready in shorter time. However, in Asian countries, windrow composting is the most popular technology as it has been used widely [15]. Shahudin (2013), has also chosen windrow composting over in-vessel composting and aerated static pile based on only the potential cost aspect as this author considers cost to be very important when starting off a composting project.

Table 3 The priorities of the sub-criteria

Criteria (priorities)	Sub-criteria	Priority
Environment	Odor	0.0932
(0.2517)	Pathogen	0.2382
	Water pollution caused by leachate	0.5065
	Water for composting process	0.1620
Economy	Capital cost	0.3275
(0.0542)	Operation cost	0.4126
	Marketing of product compost	0.2600
Social	Top management	0.6667
(0.1941)	Labor	0.3333
Technical	Machine/equipment	0.2808
(0.5000)	Maintenance	0.5842
	Time to complete composting process	0.1350

Table 4 The AHP model final synthesis result

Alternative	Normal
Window composting	0.6236
In-vessel composting	0.3765

4.0 CONCLUSION

From the synthesis, the best composting technology is windrow composting with priority of 0.6236 points while in-vessel composting with the priority of 0.3765 points. The most important factors to be considered are the technical aspects, followed by the environment, economic and social aspects. For each criterion, water pollution caused by leachate production, operation cost, top management and also maintenance are the most important factors. This method can be applied to any discipline that requires simple decision making, which is as simple as from choosing the best cereal brand in the market to complicated matters such as formulating policies

Acknowledgement

The authors gratefully acknowledge the financial support from UKM research grant AP-2012-007 and DLP-2013-019 with the cooperation of Zero Waste Group Research UKM and Department of Development and Maintenance, UKM (JPP).

References

[1] Filipović, M. 2007. The Analytic Hierarchy Process as a Support for Decision Making. *SPATIUM*. 44-59.

[2] Baby, S. 2013. AHP Modelling for Multicriteria Decision-Making and to Optimise Strategies for Protecting Coastal Landscape Resource. *International Journal of Innovation, Management and Technology*. 4(2): 218-227.

[3] Mohd Armi Abu Samah, Latifah Abdul Manaf, N. I. M. Zuki 2010. Application of AHP Model for Evaluation of Solid Waste Treatment Technology. *International Journal of Engineering Techsci*.

[4] Triantaphyllou, E. and S. H. Mann. 1995. Using the Analytica Hierarchy Process for Decision Making In Engineering Applicaiton: Some Challenges. *International Journal of Industrial Engineering: Application and Practice* (2). 35-44.

[5] Saaty, T.L. 2005. Making and Validating Complex Decisions with the AHP/ANP. *Journal of systems Science and System Engineering*. 14: 1- 36.

[6] Tiew, K. G. Kruppa S., Noor Ezlin Ahmad Basri, Hassan Basri. 2010. Municipal Solid Waste Composition Study at Universiti Kebangsaan Malaysia Campus. *Australian Journal of Basic and Applied Sciences.* 6380-6389.

[7] Zarina Shahudin, Shahrom Md Zain, Noor Ezlin Ahamd Basri, Najah Sofia Md Zaini, Nur Fatin Mat Saad, Hassan Basri. 2013. Preliminary Study for Designing a Yard Waste Composting Facility in Universiti Kebangsaan Malaysia. *Jurnal Teknologi*. 97-103.

[8] Zarina Shahudin. 2012 *Aplikasi Percubaan Kaedah Pengkomposan Dalam Pengurusan Sisa Makanan di Kafeteria UKM*. Universiti Kebangsaan Malaysia.

[9] Najah Sofia Md Zaini, Noor Ezlin Ahmad Basri, Shahrom Md Zain, Nurul Huda Mohamad, Nurul Nadiah Ishak, Zarina Shahudin. 2012. On-Site Rotary Drum Composting Process Of Cafeteria Food Waste At Ukm. *International Technical Conference*.

[10] Nur Fatin Mat Saad, Noor Ezlin Ahmad Basri, Shahrom Md Zain, Nurqaidah Nadrah Ma'min. 2012. Composting Of Mixed Yard And Food Wastes With Effective Microbes. *International Technical Conference*.

[11] Osman, K., N. Bojčetić, and D. Marjanović. 2010. Multi Criteria Decision Making In Product Platform Development And Evaluation. *International Design Conference*. Dubrovnik-Croatia, May.

[12] Nasruddin Hassan, Norfaieqah Ahmad, Wan Malissa Wan Aminuddin. 2013. Selection of Mobile Network Operator Using Analytic Hierarchy Process (AHP). *Advances in Natural and Applied Sciences*. 7(1): 1-5.

[13] Saaty, T.L. 2008. Decision Making With the Analytic Hierarchy Process. I*nternational Journal of Services Sciences*. 1(1). 83 - 97.

[14] Noor Suraya Romali, Nadiah Mokhtar, Wan Faizal Wan Ishak, Mohd Armi Abu Samah. 2013. Solid Waste Managmenet: Development of AHP Model for Application of Landfill Sites Selection in Kuantan, Pahang, Malaysia. *International Symposium on the Analytic Hierarchy Process.*

[15] Korner, I. and C. Visvanathan. 2007. Composting and Digestion - A Comparison Between Europe and Asia. *Eleventh International Waste Management and Landfill Symposium*. S. Margherita di Pula, Cagliari, Italy.