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Refuse Derived Fuel (RDF) Utilization in Cement Industry by Using Analytic Network Process (ANP)

Aysun Ozkan*, Mufide Banar
Department of Environmental Engineering, Faculty of Engineering & Architecture
Anadolu University, Iki Eylul Campus 26555, Eskisehir, Turkey
aysunozkan@anadolu.edu.tr

One of the main methods for utilizing waste is its use as an energy source. Waste is only suitable for use as a fuel if it has chemical energy content. This energy content depends most of all on the size of the (organic) combustible fraction and on the moisture content. To better employ the chemical energy contained in wastes, alternative fuels have been developed which are mixtures of different wastes. Refuse-derived fuel (RDF) or solid recovered fuel/ specified recovered fuel (SRF) is a fuel produced by shredding and mixing municipal solid waste (MSW) or industrial waste. RDF can be used in a variety of ways to produce electricity. It can be used alongside traditional sources of fuel in coal power plants. RDF can be co-incinerated in the cement kiln industry, where the strict standards of the waste incineration directive are met. That is, the desire to reduce total fuel costs through substitution of RDF for the normal fossil fuels, primarily coal, used in these facilities. Internationally, RDF has complied with Kyoto Protocol measures and is considered a renewable fuel.
In this study, Analytic Network Process (ANP) that is one of the Multi Criteria Decision Making (MCDM) tools has been used to evaluate for RDF utilization in cement industry. For this purpose, following scenarios were occurred: *Scenario 1: using of coal as a fuel; Scenario 2: using alternatives fuels* (discarded as waste tyre, oil waste etc.)*; Scenario 3a: using of 10 % RDF and 90 % coal as a fuel; Scenario 3b: using of 40 % RDF and 60 % coal as a fuel; Scenario 3c: using of 100 % RDF as a fuel.* Super Decision Software has been used for the evaluation of these scenarios and Benefit Opportunity Cost and Risk (BOCR) analysis has been done to apply ANP. In BOCR analysis, each scenario has been evaluated in terms of its benefits, costs and risks; the opportunity cluster has been examined under benefit cluster. In this context, technical, economical and social assessments have been done for the RDF utilization in cement industry. According to this assessments, the scenario 3c (%100 RDF) was found as the best scenario.

1. Introduction

Research carried out for a number of years in cement plants all over the world have clearly shown the advantages of waste utilization in clinkering processes and cement production. The decisive factors promoting the use of cement kilns for the utilization of

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wastes are: the high incineration temperature, the large area of the furnace, the significant length of the kiln and the alkaline environment inside the kiln.

There are a number of countries that use their own alternative fuels in cement plants. These fuels have different trade names and they differ in the amounts and the quality of the selected municipal and industrial waste fractions used. The fuels used should fall within the extreme values of parameters such as: minimum heating value, maximum humidity content, and maximum content of heavy and toxic metals. The incineration of an alternative fuel in cement plants is a safe method for the utilization of waste that is ecologically friendly and profitable for the industrial plants and society alike (Asthana et al., 2006).

According to the Turkish Statistical Institutes' Manufacture Industry Survey, there are 20 Mt industrial waste per year. 8 % of these wastes are recovered, 45 % are sold and 47 % are discharged. 1.12 Mt of this waste is hazardous waste. The data related to disposal of these wastes are given in Table 1. The Rules about Utilization of Wastes as Alternative Fuels is a communiqué that publish in Official Gazette in 22 June 2005 related to utilization of waste in cement industry as alternative fuel. In Turkey, waste burning license had been taken from Turkey Ministry of Environment and Forestry for 34 cement factory based on this regulation up to April 2010. Types of the wastes used as fuel in these factories are given in Table 2 (Ministry of Environment and Forestry of Turkey, 2008).

Table 1 Capacity of Hazardous Waste Treatment/Disposal Facility in Turkey

Name of the facility	*Capacity (November 2007)*
İZAYDAŞ (landfill)*	790,000 m^3
İZAYDAŞ (incineration)	35,000 t/y
PETKİM (incineration)	17,500 t/y
TÜPRAŞ (incineration)	7,750 t/y
ERDEMİR (landfill)	6,084 t/y
İSKEN İZAYDAŞ (landfill)*	115,000 m^3
* total capacity	

Table 2 Types of The Wastes Used As Fuel In Cement Factory In Turkey

Types of the waste	*Licensed amount (t/y) (November 2007)*
Waste oil	214,226
Waste tire	106,458
Contaminated waste	61,884
Plastic waste	51,866
Wastes of petroleum refinery	24,120
Petroleum bottom sludge	18,902
Dye sludge	16,964
Liquid fuel sludge	4,020
Total	498,440

Therefore, in this study, Analytic Network Process (ANP) that is one of the Multi Criteria Decision Making (MCDM) tools has been used to evaluate for RDF utilization in cement industry. For this purpose, following scenarios were occurred: *Scenario 1: using of coal as fuel; Scenario 2: using alternatives fuels; Scenario 3a: using of 10 % RDF and 90 % coal as fuel; Scenario 3b: using of 40 % RDF and 60 % coal as fuel; Scenario 3c: using of 100 % RDF as fuel.* In this context, technical, economical and social assessments have been done for the RDF utilization in cement industry.

2. The Analytic Network Process (ANP)

The Analytic Network Process (ANP) was developed by Saaty (2001), provides a way to input judgments and measurements to derive ratio scale priorities for the distribution of influence among the factors and groups of factors in the decision. The ANP is a coupling of two parts.

The first consists of a control hierarchy or network of criteria and sub criteria that control the interactions in the system under study. The second is a network of influences among the elements and clusters. The network varies from criterion to criterion and a super matrix of limiting influence is computed for each control criterion. Super matrix is a two-dimensional matrix of elements by elements.

The priority vectors from the paired comparisons are placed in the appropriate column of the super matrix. As the super matrix is built in this way, the sum of each column corresponds to the number of comparison sets. Finally, each of these super matrices is weighted by the priority of its control criterion and the results are synthesized through addition for all the control criteria. In addition, a problem is often studied through a control hierarchy or system of benefits, a second for costs, a third for opportunities, and a fourth for risks. The synthesized results of the four control systems are combined by taking the quotient of the benefits times the opportunities to the costs times the risks to determine the best outcome (Ulutaş, 2005).

ANP applications have been noticeably limited when compared with AHP, due to its complexity and time consuming nature. So far, the ANP approach has proven itself to be successful when expert knowledge is used within environmental applications (Promentilla et al., 2006; Tran et al., 2004; Kone and Buke, 2007).

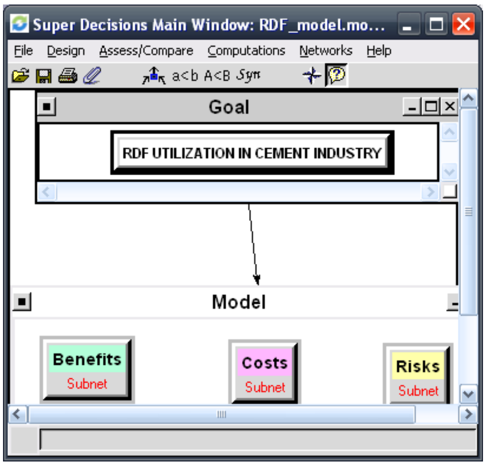
The decision makers are asked to make pairwise comparisons of the criteria of the network using a nine point scale suggested by Saaty (2001). While the basic ANP structure consists of only one network, the most complex one can analyze the benefit, opportunity, cost and risk that each alternative can cause together.

The important issue is that benefit, opportunity, cost and risk may have different significance degrees according to the problem. This weighting procedure is called Benefit Opportunity Cost Risk (BOCR) analysis. It note that for costs and risks one must ask which is more costly and more risky (not which is less costly and which is less risky) because in paired comparisons we can only estimate how much more the dominant member of a pair has a property as a multiple of how much the less dominant one has is and not the other way around (Saaty, 2001).

3. Methodology

In this study, it was used following process:

- Designation of scenarios,
- Formation of decision-makers group,
- Determination of criteria,
- Formation of BOCR model by using Super Decision software (see the Figure 1 for a sample),
- Determination of values and weights of criteria (see the Figure 2 for the sample),
- Evaluation and interpretation of results.



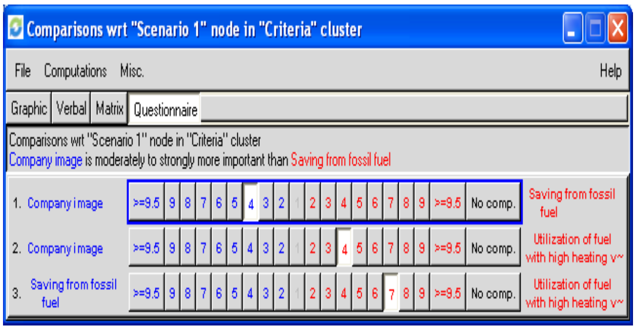


Figure 1: BOCR model in this study

Figure 2: A sample for weights of criteria

In this study, 5 scenarios were created in the scope of ANP management for evaluate for RDF utilization in cement industry:

- *Scenario 1:* using of coal as fuel;
- *Scenario 2:* using alternatives fuels discarded as waste tyre, oil waste etc.
- *Scenario 3a:* using of 10 % RDF and 90 % coal as fuel;
- *Scenario 3b:* using of 40 % RDF and 60 % coal as fuel;
- *Scenario 3c:* using of 100 % RDF as fuel.

Super Decision Software has been used and BOCR analysis has been conducted to apply ANP for evaluation of RDF utilization. In BOCR analysis, each alternative scenario has been evaluated in terms of its benefits, costs and risks; the opportunity cluster has not been considered. Also, it has been used a committee including members from both a cement company and university as a decision maker. It was bewared that the consistency ratios were less than 10 % due to the nature of the method which was an evident fact.

In Analytic Network Process, significance and impact weighting between each criterion might be done according to decision maker. In this study, the significance of the weights of chosen criteria has been formulated in the program as;

Formula: bB + oO + c (l/C) + r (l/R) (1)

r: 1/2; c: 1/3; b: 1/6; o: 0
Scenarios have been evaluated according to the criteria that are below:

Criteria in benefit cluster:

- *Utilization of fuel with high heating value:* In this criterion, evaluation has been done according to the high heating value because of decreasing of fuel amount. Therefore, scenarios having RDF has been the more advantageous scenarios.
- *Saving from fossil fuel:* Depletion of fossil fuel has been decreased with using of wastes as fuels. For that reason, it has been considered that the most advantageous scenario is scenario 3c.
- *Company image:* Environmental benefits of RDF using can be positively affected on peoples. Therefore, scenario 3c is the most advantageous scenario.

Criteria in cost cluster:

- *Preprocessing costs:* It has been considered that preprocessing cost for fuel preparation (grinding etc.). In this criterion, systems which are containing to RDF are the more costly scenarios.
- *Fuel costs:* It has been considered that fuel costs for RDF is less than the fossil fuel.
- *Analysis costs:* For controlling of emissions, gas analysis should be realized according to Control of Air Pollution from Industrial Plants for fossil fuels and according to The Rules about Utilization of Wastes as Alternative Fuels for RDF. Analysis costs will be more costly in systems uses wastes than the other because of several analysis parameters in the rules about alternative fuels.
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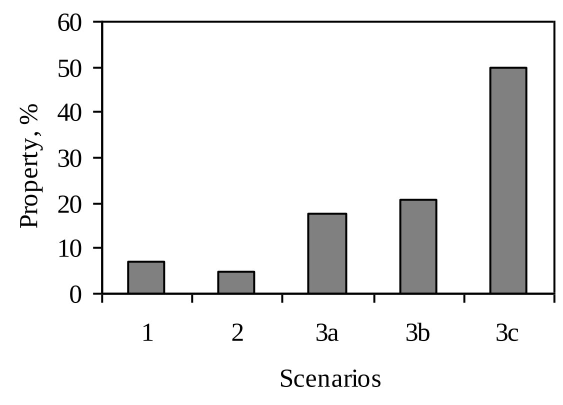
Criteria in risk cluster:

- *Regular fuel acquisition:* It is important that regularly fuel acquisition is very important for sustainability of system. For that reason, it has been considered that acquisition of wastes is risky.
- *Emissions (Standard combustion components):* SO_2, NO_x, CO_2 emissions in waste usage are lower than the fossil fuel usage according to literature survey.
- *Emissions (Toxic components):* Contrary to standard combustion components, toxic gas emissions (PCDD/PCDF, VOC, PCB etc.) in waste usage are higher than the fossil fuel usage because of chlorine content in wastes especially.

4. Results and Conclusion

In this study, Analytic Network Process (ANP) has been used to evaluate for RDF utilization in cement industry. For this purpose, five scenarios were occurred. In this context, technical, economical and social assessments have been done for the RDF utilization in cement industry. According to the criteria and the formula above, the appropriate order of scenarios has been evaluated and presented in Figure 3. According to this figure, the scenario 3c (%100 RDF) was found as the best scenario. But, this scenario it can be suitable for real application because of risk of regular waste acquisition. For that reason, scenario 3b (%40 RDF + % 60 fossil fuel) which is following the scenario 3c will be more suitable than scenario 3c. Establishment of a strategy is very important both for the protection of natural resources and prevention of environmental pollution. In setting up this system, different instruments will be used to help the decision makers for the most appropriate solution.



1 (Scenario 1): using of coal as fuel;
2 (Scenario 2): using alternatives fuels discarded as waste tyre, oil waste etc.
3a (Scenario 3a): using of 10 % RDF and 90 % coal as fuel;
3b (Scenario 3b): using of 40 % RDF and 60 % coal as fuel;
3c (Scenario 3c): using of 100 % RDF as fuel.

Figure 3: Total comparison results of all scenarios

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