MULTICRITERIA ANALYSIS MODEL FOR THE MANAGEMENT OF USED TYRES: CASE STUDY OF ATTIKA - GREECE

D. DAIS, M. LOIZIDOU, A. PAPADOPOULOS AND D. FATTA*

National Technical University of Athens, Department of General Chemistry, Athens

SUMMARY: The disposal of used tyres is an issue that preoccupies not only Greece, but also every other country with terrestrial means of transportation. The problem occurs due to the enormous volume of tyres, which are disposed, each year. The high calorific value of the tyres is an additional reason that suggests the implementation of a more effective and efficient process. A multicriteria analysis model was developed in order to evaluate the existing techniques for the reprocessing of used tyres. The criteria taken into account were of economical, technical, socio-political and environmental nature. Actors involved in the “tyre chain” determined relative weights of the criteria. The output of the software used, indicated the combustion in cement kilns as the most essential method by all odds, while mechanical shredding is a comparable alternative.

1. INTRODUCTION

1.1. Present status in Greece

According to the sales of new products, about 43,000 ton (1997) of used tyres are produced in a yearly base in Greece. One should bear in mind that Greece is a developing country, whose number of vehicles in use is still expanding with an average rate of 7% per year. So, it is quite obvious that used tyres is becoming year by year an increasingly difficult, to deal with, waste stream.

1.2. EC Directions

Greece as a Member-State of the European Community has to comply with the European policy. In 1989, the Commission produces an inventory among Members-States, where it identifies used tyres as one out of thirty main waste streams that, due to their impact on the environment, should be taken into consideration for particular attention at EC level.

In the Fifth Environmental Action Programme (1992), among others:

- Recognises that till then, its governance concerning environmental issues “has largely been based on legislation and controls involving government and manufacturing industry” (5th Action Programme, Chapter 3, p.26),
- Introduces the shared responsibility principle, according to which all sectors of the society
(public administration, public and private enterprises, individual citizens and consumers) have to get involved, and

- Strengthens the horizontal approach on decision-making.

In 1994, the Directorate General XI proposes to “…abandon, before the year 2000, the traditional disposal techniques (incineration without energy recovery and especially landfill)…” (Proposal from the Working Group to the European Commission for a Recommendation on the Prevention, Recovery and Disposal of Used Pneumatic Tyres, Chapter 3, p.3). It is also appointed the hierarchy of the options (prevention, recycling and recovery) that should be followed, in order to achieve the previously described target.

In the spirit of the above principles the most widespread methods regarding the reprocessing of used tyres are going to be evaluated. The methods that were examined are briefly presented afterwards.

1. Mechanical Shredding: The material is cut into pieces up to 600-800 µm through a purely mechanical manner. Firstly the tyres are shredded up to 3/4 inches, the removal of metal parts and fibres follows and lastly, a further shredding takes place till the final product.

2. Cryogenic Grinding: The method is similar with the above. The difference is that the grinding of the polymer is achieved through a cooling device, which subjects the material to \(0\) °C temperature. Therefore, the removal of metal parts and fibres becomes easier.

3. Thermal process (“Dry Distillation” Technique): The tyres are processed through a two-zone burner. In the first zone the tyres are thermolyzed in the absence of air, while in the second zone at the lower part of the burner they are burned in the presence of air. The temperature varies from 500 to 900 °C. The final products are oil, gases, Carbon Black, tar and wires.

4. Combustion in cement kilns: The method is based on the total combustion of the tyres within the cement kiln. The temperatures in the cement kilns are such, that the tyres are almost instantly burned, without any residue left.

5. Co-processing with coal: Tyres are granulated and then they are burnt with coal (tyres:coal=1:6). The temperature in the furnace rises up to 1500 °C and superheated vapour is produced. The produced vapour is used for the operation of two turbines, which produce electricity.

6. Pyrolysis: The tyres are conveyed to the pyrolytic reactor where heated gases (600 °C), in the absence of oxygen, are also introduced. The organic matter of the tyres is subjected to degradation (cracking of the carbonic chains). Finally solid carbon fraction, high level steel, non-condensable gases and oil fraction are produced.

7. Vacuum Pyrolysis: The method is an evolution of the previous one. Tyres after been preheated, are heated in the pyrolytic reactor and from their fission heavy as also light oil, steel, Carbon Black and non-condensed gases are produced.

2. METHODOLOGY

Even for the simplest decision that one has to make several criteria have to be considered; criteria, which in many cases are contradictory. So as to evaluate different scenarios in a Decision-Making process, Multicriteria Analysis Support Tools are used. In our case the Electre III tool (PC Version), was implemented.

The Electre III is multi-criteria method where the competitive scenarios are evaluated regarding a number of criteria. These criteria should be very carefully selected, since they are factors of great importance regarding the success of the decision-making process.
Electre III is based on the binary comparison between the different scenarios, so as to assess the relation of each scenario with all the rest. In this way the scenarios are classified in a rank based on the preference of one scenario towards another one.

The main principle of the method is the concept of the **pseudo-criteria**. The difference, of the real criteria vis-à-vis the pseudo-criteria, is that the first ones may have only two possible regions, the **strict preference region** and the **indifference region**, while the second ones may also have a third one, the **weak preference region**.

The scenarios are finally classified through the appliance of two distillations:

- **An ascending distillation** where a repetitive process determines smaller and smaller aggregations of scenarios that have greater preference, and
- **A descending distillation** where the exact opposite process takes place.

In our case seven (7) scenarios were evaluated concerning ten (10) criteria. The scenarios as also the criteria that were used are presented in Table 1.

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>MECH</td>
<td>C1 Investment cost</td>
</tr>
<tr>
<td>CRYO</td>
<td>C2 Operating and maintenance cost</td>
</tr>
<tr>
<td>COMB</td>
<td>C3 Marketability</td>
</tr>
<tr>
<td>CEME</td>
<td>T1 Capacity</td>
</tr>
<tr>
<td>COAL</td>
<td>T2 Recovery percentage</td>
</tr>
<tr>
<td>PYRO</td>
<td>S1 Social acceptance</td>
</tr>
<tr>
<td>VACU</td>
<td>S2 Compliance with the EC’s policy</td>
</tr>
<tr>
<td></td>
<td>E1 Air emissions</td>
</tr>
<tr>
<td></td>
<td>E2 Solid residue</td>
</tr>
</tbody>
</table>

### 3. RESULTS – DISCUSSION

The results that come as an output from the Electre III software package are diagrams in a Cartesian system of co-ordinates (see Figure 1). The horizontal axis represents the ranking of a scenario regarding its performance in all the criteria according to the descending distillation, while the vertical axis represents the ranking of the same scenario according to the ascending distillation.

The best scenarios are concentrated in the right-up corner of the diagram. Scenarios whose values are scattered or they are away from the main diagonal are considered as non-comparable.

Apart from the Basic Solution, four Sensitivity Analysis were performed, so as to test the credibility of the results.

The results out of the implementation of the Electre III software in our case study are presented in Figures 2 to 8. According to them, the scenarios can be categorised as follows:

- All or most of the points are located in the “best scenarios” area (CEME, MECH).
- All or most of the points are located outside the “best scenarios” area (CRYO, COMB, PYRO, and VACU).

The points are scattered or located away from the main diagonal (COAL).
Figure 1. Form of the diagram that the Electre III software provides as an output.

Figure 2. VACU

- Basic Solution (all criteria are taken into account)
- Sensitivity Analysis 1 (criterion T3 was not taken into account)
- Sensitivity Analysis 2 (criterion T1 was not taken into account)
- Sensitivity Analysis 3 (criterion E1 was not taken into account)
- Sensitivity Analysis 4 (criterion S1 was not taken into account)
4. CONCLUSIONS

It is quite clear that the “best” scenario is the combustion in cement kilns, since it is dominant for all the criteria. Up to 15% percent replacement of conventional fuel is acceptable, so as not to induce any problems on the production line, which is well covered by the energy that used tyres provide.

The mechanical shredding stands out of the rest scenarios, having almost all its points in the “best scenarios” area. Before the implementation of such a scenario, it is demanding to predetermine and to assure the existence of a market for the granulated product.

From the rest, vacuum pyrolysis seems very promising, but also needs a predefining of its products’ marketability.

No matter how, in order to promote any of the above solutions for the case study of the Attika region, in an economically feasible way, it is essential to develop a well organised collecting system of the used tyres.

5. REFERENCES

D.Dais (1998), "Development of a Multicriteria Analysis Model for the management of used tyres (in Greece)", National Technical University of Athens (Greek).