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Decision support tool for used oil regeneration technologies assessment and selection

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Abstract

Regeneration is the most efficient way of managing used oil. It saves money by preventing costly cleanups and liabilities that are associated with mismanagement of used oil, it helps to protect the environment and it produces a technically renewable resource by enabling an indefinite recycling potential. There are a variety of processes and licensors currently offering ways to deal with used oils. Selecting a regeneration technology for used oil involves 'cross-matching' key criteria. Therefore, the first prototype of spent oil regeneration (SPORE), a decision support tool, has been developed to help decision-makers to assess the available technologies and select the preferred used oil regeneration options. The analysis is based on technical, economical and environmental criteria. These criteria are ranked to determine their relative importance for a particular used oil regeneration project. The multi-criteria decision analysis (MCDA) is the core of the SPORE using the PROMETHEE II algorithm.

Keywords: Decision support tool; Multi-criteria decision; Outranking methods; Regeneration; Waste oil

1. Introduction

Waste oil is a term defined by European law as any semi-liquid or liquid used product, totally or partially consisting of mineral or synthetic oil, including the oily residue from tanks oil–water mixtures and emulsions (Council Directive 75/439/EEC). Waste oils are classified as hazardous waste by European law and should be collected so that they can be safely treated. Common waste oil contaminants include trace metals and chlorinated solvents: gasoline and products of incomplete combustion, polynuclear aromatic hydrocarbons (PAHs), glycols, water and polychlorinated biphenyls (PCBs). The term of "used oil" is used in this work to refer to the waste oils arising from the use of lubricating oils.

There are a wide variety of processes and licensors currently offering ways to deal with waste oils. There are four main processes used for the treatment of waste oils; blending, separation-chemical treatment, distillation and cracking. In all channels, the economic and calorific values of the used oils are recovered to varying degrees. The two main techniques used are regeneration (or re-refining) and direct burning (mainly in cement factories). The two other methods which, together, account for the remaining third are reprocessing and reclaiming, the latter being used principally for hydraulic oils. According to Monier and Labouze [1], about 2400 kt of waste oils were generated in 2000, approximately 1730 kt were collected and the remaining 675 kt are accounted as illegally burnt or dumped in the environment. Only 32% of collected waste oil is regenerated to base oils.

The regeneration of waste oil has grown in recent years through a better understanding of environmental benefits and the economic and technological advances that make re-refined oil dependable and efficient. Multiple and sometimes conflicting criteria need to be considered simultaneously when deciding if and under which conditions to undergo the questionable waste oil regeneration process, and which particular regeneration technology to use, since there is a market boom of the readily applicable technologies, while some new and innovative ones are also emerging and being patented. To help its target beneficiaries (investors, environmentalists, policy makers, technologists, etc.) from developing world to catch up with developed

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countries regarding waste oil management, the ICS-UNIDO has undertaken the development of repository of the best available technologies for waste oil regeneration [2], together with the first prototype of SPORE web-based decision support tool for the assessment and selection of the most suitable technology to regenerate particular waste oil, taking into account the specific needs and preferences of various stakeholders (including technology maturity, quality of the product, yield of the main product, operating cost, by-products, etc.).

The paper first presents the methodology used to develop the first prototype of SPORE decision support tool. The second part presents a demonstration of the implemented prototype.

2. Generic framework of SPORE

The generic framework of SPORE was developed using web-based intelligent systems environment (WISE) that could be easily configured for the specific decision support system [3]. WISE represents a set of Java packages with specific organization and usage that could be freely and easily combined into a consistent whole, according to the specific problem at hand.

The following are the three main functional packages of WISE:

- WISE.ES, the package facilitating the development of conventional, rule-based expert systems in Java language.
- WISE.MCDM, the package facilitating the multi-criteria decision making process, offering the most widely used methods, PROMETHEE II.
- WISE.FUZZY, the package facilitating fuzzy sets, fuzzy production rules, and fuzzy linguistic functions (usually used together with WISE.ES package).

For SPORE decision support tool, WISE.MCDM package represents the core module. WISE.MCDM package facilitates the multi-criteria decision making process and implements the most popular MCDM algorithms of the “outranking” type PROMETEE II [4].

Outranking methods represent binary relations between alternatives, given the preference of the decision maker, the quality of the valuations of the alternatives and the nature of the problem [5].

3. WISE.MCDM package architecture

Using WISE packages it is very easy to create the skeleton of every web based intelligent decision support tool. Fig. 1 shows the core WISE-based decision support system architecture used.

A concrete web based decision support tool consists of graphical user interface (GUI), central WISE layer and knowledge and data warehouse [6]. GUI can be realized as standard web application which is realized using standard script languages (it is possible to use Java server pages and also active server pages technologies with JavaScript and VBScript languages). Structured query language (SQL) has been chosen for SPORE decision support tool to support the relational database management system (RDBMS).

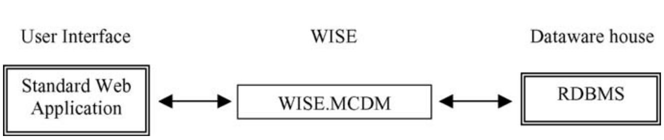

Fig. 1. WISE based decision support tool architecture.

4. SPORE structure

The first prototype of SPORE has been designed and implemented over a multi-criteria decision analysis (MCDA) system and utilizes a reference data-base in which used oil regeneration technologies are classified in three broad categories according to their development stage; technologies with proven industrial applications, those at pilot stage, and those that are only emerging from R&D laboratories, or currently being patented. The database is based on the information of the ICS-UNIDO compendium on used oil regeneration technologies [2] as well as from the EC Directive of Integrated Pollution Prevention and Control [7]. The compendium is based on compiling readily available information from the literature or personal communications with involved technology owners/vendors/inventors.

The first prototype includes totally 21 technologies and nine ranked criteria. The structure of the data-base and the technologies available in the current stage of the first prototype are shown in Table 1. The criteria used for the prototype implementation are also indicated in Table 1.

To evaluate technologies which are performed with SPORE, some criteria have been selected and a specific rating system has been developed. Each technology has then been rated according to its performance under each criterion.

Table 1
List of available technologies and criteria used for SPORE implementation

Development stage	Technologies	Product	Criteria
Industrial applications	Mohawk		Yield of the main product
	Revivoil		Quality of the product
	Atomic vacuum distillation		Stream factor
	Blowdec	Base oil	Development stage
	Cyclon		Operating cost
	Enviro-tech		Estimated capital cost
	Meinken		PCB’s removal
	Prop		By-product quality
	Acid/clay purification		Solid wastes existence
	Snamprogetti		
	Sotulub		
	Vaxon		
	KTI-Relube		
Prototypes and pilot stage	Interline	Base oil	
	Entra		
	Mrd-Kernsolvat-Extraktions		
Studies and patents	UOP Hylube	Base oil	

Not all the stakeholders are equally interested in the criteria listed above. Investors are more interested in capital cost than the environmental acceptability of certain technology, while the local community and/or the environmentalists have exactly the opposite viewpoint. Therefore, the prototype enables its user to select the subset of the criteria offered by the tool to be taken into account in particular MCDA session, as well as to put the relative weights to the chosen criteria that best reflect their specific preferences.

5. Prototype demonstration

The software provides a repository of the best available technologies for waste oil regeneration, a set of indicators for criteria for evaluating those technologies, and default values of weighting factors, that could be easily adjusted to suit the user's specific needs and preferences. The first prototype of SPORE is web-based application, so that target beneficiaries from developing countries, could easily access it, once they are properly authenticated. It is very easy to add new technology or even a category of technologies, or change the parameters of the existing ones, or introduce new preference functions, etc. The software presents its users with a variety of configuration and input parameters from which to choose. Several are mandatory (such as identifying technologies to be evaluated), but there are many that the user can choose to leave blank or use the supplied default values. This way, the user decides how to tailor the analysis to satisfy his/her specific needs.

MCDA of all the factors involved in the decision process determines whether a waste oil regeneration strategy is a feasible, effective and efficient solution and whether it satisfies all criteria and constraints defined by the user. Depending on the context in which waste oil regeneration technology assessment and selection is performed, the user can tailor decision strategy balancing out various effectiveness and efficiency parameters, other criteria and constraints. From the user's point of view, the general algorithm for SPORE analysis is described in Fig. 2.

The user of the prototype, after inputting data relevant to the waste oil to be treated, uses a full set of technologies or indicates

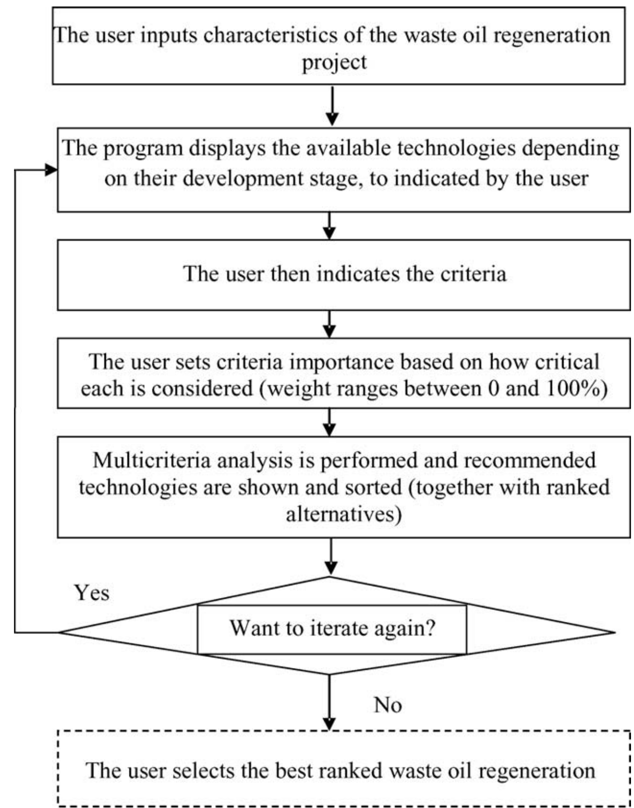

Fig. 2. General algorithm supported with SPORE.

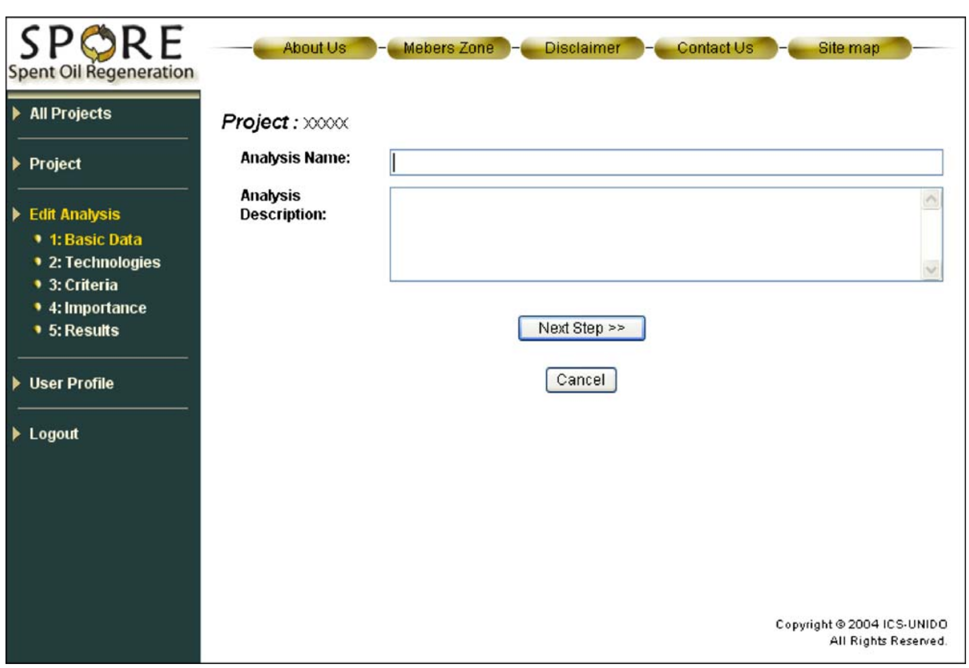

Fig. 3. Main analysis window for the creation of a new waste oil project.

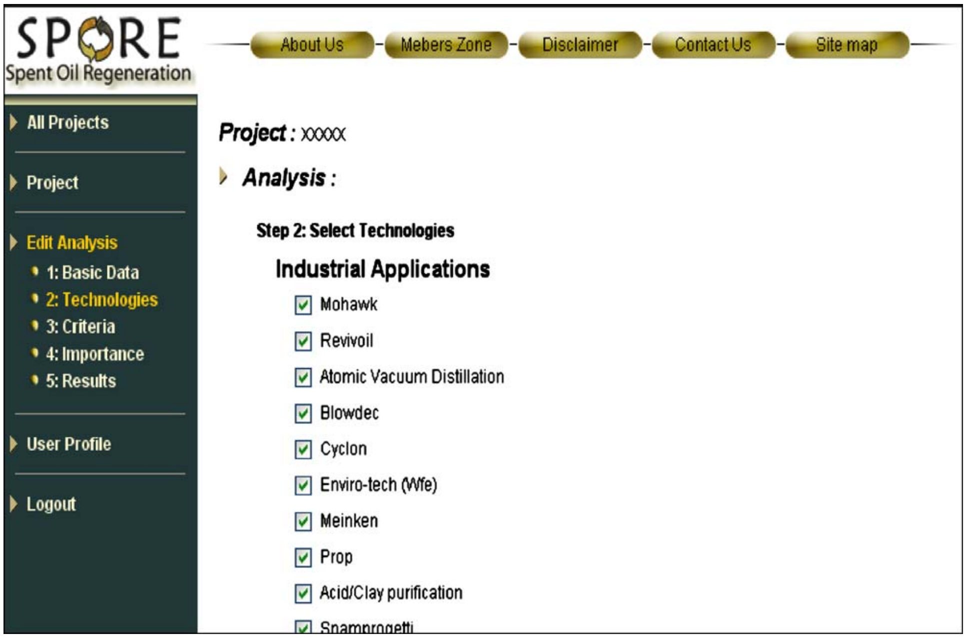

Fig. 4. List of technologies to be indicated during analysis.

a subset of technologies in which there is interest, ranked criteria, and corresponding weighting factors.

After the criteria are selected and their relative preferences set by the user, the MCDM process starts, and the system recommendation as well as ranked alternatives are presented to the user.

Fig. 3 shows the application's main analysis window which consists of the current state of configuration, and a few dialogs for data entry purposes for creating a new analysis. It is connected to the database that contains previously entered information on available technologies and selection criteria; database should be registered by the user and/or software administrator.

Dialogue boxes requesting the user to indicate the technologies to be simultaneously evaluated and list of criteria to be considered are shown in Figs. 4 and 5.

Fig. 6 shows a window of set criteria importance used to overview the values of all selected criteria for particular technology. A window multicriteria analysis results (Fig. 7) is used for the presentation of the results of the multicriteria analysis process.

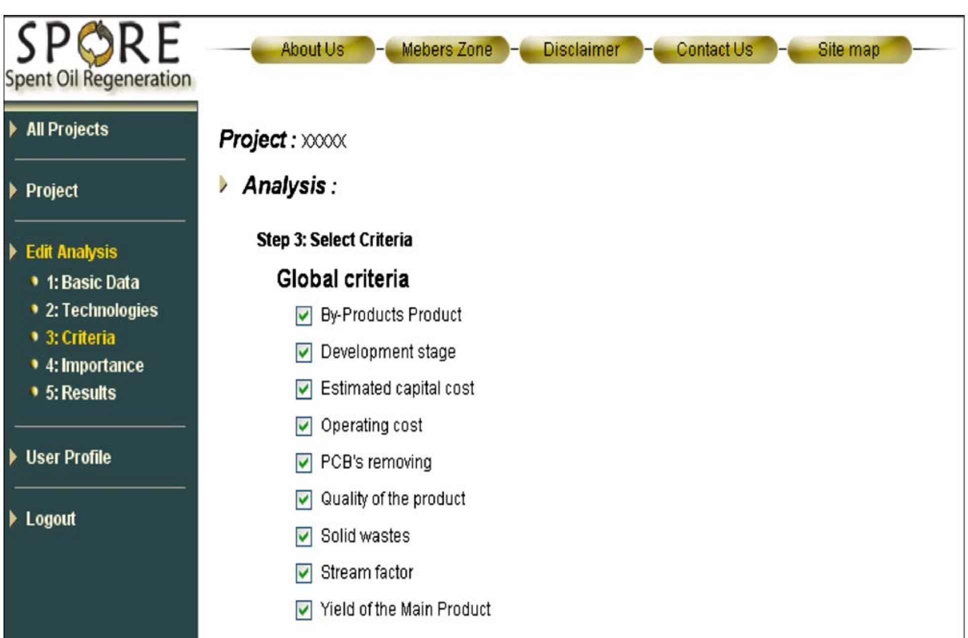

Fig. 5. List of criteria to be considered.

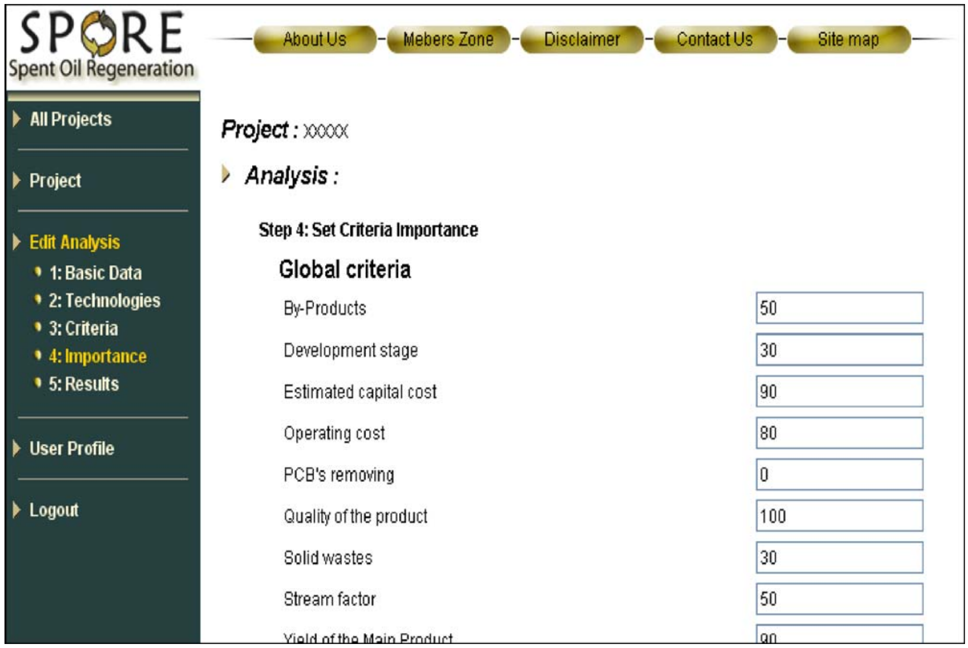

Fig. 6. Setting weight for chosen criteria.

Technologies were sorted by decrescent order of recommendation for a random selection of input criteria. The presented multicriteria analysis process results are exclusively intended to be as output from a test-phase of the system and not representing a real case of application.

The prototype has its limitations (such as unable to replicate some human decision making skills; may not match decision making's mode of expression and constrained by the knowledge it possesses) and could not be used alone to reach an optimum selection. The compromise solution depends strongly on the decision maker's personality, on the circumstances of the decision aiding process and on the way the problem is presented and on the method, that is used [5]. It may pose the challenge of integrating SPORE with other decision support tools (e.g. decision support tools derived from life cycle analysis).

As Guariso and Werthner [8] already pointed out, environmental decision support system will not and cannot do the work

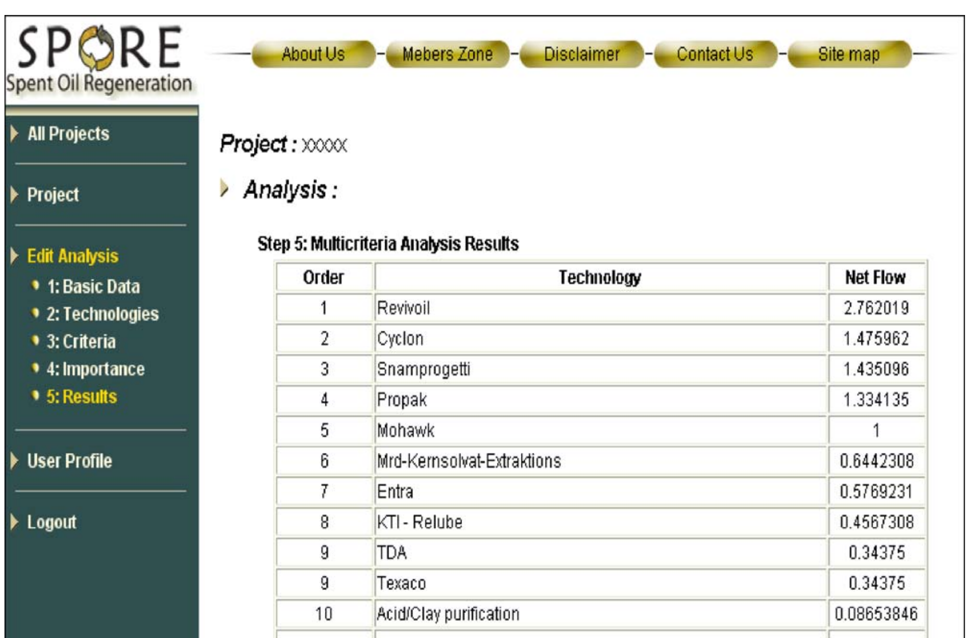

Fig. 7. Multicriteria analysis results.

that remains to be done by humans. Better computer support does not automatically imply a better decision. It is still the human's responsibility to be aware of the environmental situation of the planet and to cope with all the problems connected with it.

6. Conclusions

To help target beneficiaries of ICS-UNIDO from developing countries to catch up with developed countries regarding waste oil management, the first prototype of SPORE decision support tool has been developed. It is a Web-based decision support tool that allows assessing the available waste oil regeneration technologies against various technical, environmental and financial criteria, and selecting the most suitable technology according to the specific objectives and preferences of a particular user/stakeholder. The first prototype is currently being completed and is a subject of internal validation by means of test-runs utilising data gathered from assessed full-scale applications and verification process before being posted on the web for wider testing by beneficiary institution and/or individuals. Further work is being undertaken to split the list of criteria and update the development stage of some technologies as well as addition of new technologies available in the market.

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