ICIC Express Letters
Volume **14**, Number **12**, December **2020**
 ISSN 1881-803X
pp. **1139–1146**

ADVANCED FUZZY ECO-DSM FOR MEDICAL WASTE TREATMENT

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Received March 2020; accepted June 2020

Abstract. *Decision support model (DSM) is familiarly applied in a lot of areas and issues. The model is commonly benefited by decision maker to solve semi/unstructured problems. In Indonesia, the issue of waste is challenging. This issue requests a restrictive and judicious treatment to execute, as a ruinous outcome for all intents and purposes created from inaccurate technique usage in treating is wide extending, especially for human's life and well being and furthermore for the condition. This research offers a conventional shrewd ecological decision support model (Eco-DSM) for treating medical waste. The numerical model dependent on fuzzy logic conception joined with the other heuristic improvement technique is worked to quantify and legitimize six choices of treating strategy decisions. The experiment involved 5 types of waste (general waste, sharp waste, infectious waste, pathological waste and hazardous waste) and 6 medical waste treatment methods (incinerator, autoclave, microwave, mechanical processing and chemical disinfection, vitrification and landfill).*
Keywords: Decision support model, Fuzzy logic, Medical waste, Hospital, Waste management

1. **Introduction.** The expansion of hospitals, health facilities, and the use of safer medical devices cause an increase in the amount of waste produced by hospitals or health service units both domestic waste (plastic, paper, and food waste) and medical waste. The increase in an amount of hospital waste has the potential to pollute the environment, and instigate unpleasant odors and the possibility of causing accidents and disease transmission to health care workers and the general public, especially those who make direct contact with waste [1,2].

Also, [3-6] led an research that concentrated on the choice of medical waste treatment technique which for the most part comprises burning utilizing incinerators, cleansing via autoclave, microwave, and transfer of the spot of conclusive transfer (landfill). [7] developed a decision support model (DSM) in picking the transfer area of therapeutic waste utilizing fuzzy-AHP technique to ascertain chosen criteria loads and fuzzy-TOPSIS to rank such an area. Moreover, [8] constructed a DSM focusing on infectious waste.

The decision to select technology to treat medical waste is complex and turns into a test for the world, particularly for nations that frequently blend their medical waste with urban waste. Every nation and city, particularly wellbeing administrations, have distinctive qualities as far as physical condition, institutional association, city limit, account, sociocultural, and financial [9].

A DSM is a model possibly worked to solve problems regarding waste. With its ability and uniqueness, and by considering several recognizable parameters, the model is skilled for supporting decision maker in deciding a crucial decision, deliberately in treating the waste.

DOI: 10.24507/icicel.14.12.1139

This research uses main method fuzzy logic. Fuzzy logic is part of one of the fields of computer science regarding artificial intelligence. It is an effective way to describe human perception of the problem for decision making. Therefore, it portrays an ecological DSM (Eco-DSM) that is operated to support decision maker to practically treat medical waste, which has economic and environmental impacts. One hospital in Jakarta (Indonesia) and several types of medical waste were selected as a research object in this study.

The constructed Eco-DSM is a knowledge contribution offered by the study explained in detail in this paper. It is also able to be operated by decision maker practically in well managing medical waste. The paper's section introduction is followed by sections Related Works, Research Methodology, Result and Discussion, and Conclusion and Further Works.

2. **Related Works.** There are many studies that have been done discussing medical waste. Also, this research is an extended version from [8] and [10], where the researches operated three medical waste treatment methods and three types of waste. Fuzzy logic was operated together with Euclidean distance to produce recommendations that were best mathematically. The parameters in the previous study were modified by adding three more medical waste treatment types and several parameters. Fuzzy logic method was applied together with Euclidean distance measurement to produce the fittest value. While, the optimization method is operated in the study of simulated annealing. On the other hand, [10] conducted a study about modified version of [8] conceptually, and continued in more complete in this study.

[11] created a DSM for assessing partnership. Fuzzy logic and analytic network process (ANP) were two main methods used in the study, where two strategies were separately utilized for evaluating unsure measurements and assessing the measurements' significance. [12] built up a DSM for antibiotic selection, in the event of Gram-negative bloodstream contamination. The model depended on three clinical choice edges of consideration (80%, 90%, and 95%).

[13] evaluated three medical waste management engineering scenarios and focused on small-scale health facilities using decision-making tools. The environmental impact and cost analysis of each technique were evaluated using the life cycle assessment (LCA) and life cycle cost (LCC). [14] conducted a study that provided an evaluation of the medical waste management system in five health facilities in Southwest Cameroon. In this study, categorizing types of medical waste into four categories was done, namely non-medical waste, sharp objects, infectious waste, and chemical waste, pharmaceuticals.

3. **Research Methodology.** This study was directed through three main stages (Figure 1): preliminary study, situational analysis, and model construction. In the first stage, preliminary study was done by systematic review that relates to the topic. A lot of papers which are associated to medical waste topic, DSM and environmental aspects

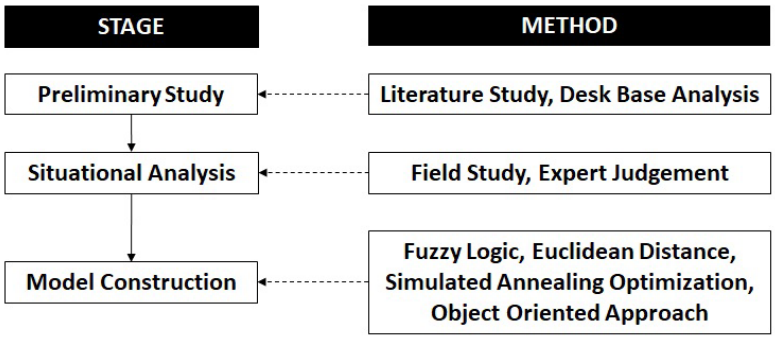

FIGURE 1. Research stages

were systematically reviewed. The aim is to understand the topic better, know well the position of the research among other researchers, and locate the research gap.

Then, in situational analysis, the research object was explored deeper. Field study was executed, and experts were benefited to evaluate parameters via judgement. Finally, the model was constructed in the last stage, in model construction stage, by operating all previous results. In the last stage, several scientific methods were operated.

The method fuzzy logic is a fundamental method operated in this study. Types of medical waste parameter and types of medical waste treatment parameter are numerically processed through this method. Particularly to judge the parameters (environmental impact, land need, treatment effectiveness, capital cost, operating cost, volume reduction, reliability, and waste type), experts are occupied, where the waste type is divided into few types: general, pathological, sharp, infectious, and hazardous. The experts involved to evaluate the properness between parameter and types of decision alternatives (types of treatment strategy) via the triangular membership function of fuzzy logic.

Object-oriented is a selected approach to develop the model. Specific tools are used to structure: class, activity, and component diagrams. They separately depict the interaction pattern among entities, process flow, and interconnection of component in the model. By utilizing this technique, every model aspect is delivered in high-level configuration [15,16].

Class diagram is describing the structure of the model in terms of defining the classes that will be made to build the model. Class-based modeling basically shows objects that will be manipulated by the model or software, paying attention to operations that will be applied to objects to produce certain effects on object manipulation, showing relations between objects and showing collaboration that occurs between the classes defined.

Furthermore, activity diagram operated to model all possible processes in the model. The algorithm of the model is deeper depicted by using such a diagram. Then, component diagram helps the modeler to see all parts in the model. Usually, one component is able to solve one case of problem.

The method fuzzy logic is operated to justify the fuzzy value of parameters. This method possibly makes the model can adopt human linguistic variables. The process of fuzzification-defuzzification theoretically realizes it [17]. The method is also ever functioned by [18].

The Euclidean distance calculation is utilized to fit medical waste and medical waste treatment. The strategy is a measurement approach to calculating a distance between two nodes, or among a few nodes. Mainly, it very well may be utilized to compute the likeness of two things. In this research, the value of the similarity is utilized to depict the gap between medical waste with medical waste treatment [19].

4. **Result and Discussion.** The constructed DSM is started through Figure 2 (acitivity diagram). It is the decision-making algorithm of the model that works for the medical waste treatment, where it will start from the Input Waste Data, where input is needed into the waste data model for all waste types. Then the data inputted were processed

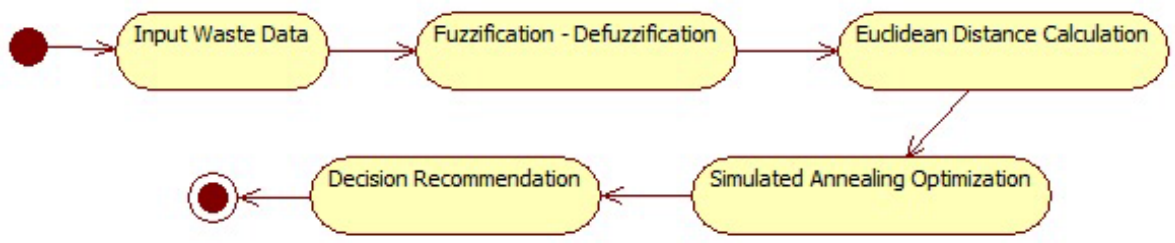

FIGURE 2. Activity diagram for the constructed model

in fuzzification-defuzzification mechanism to produce fuzzified value in between and final crisp value. The Euclidean distance calculationis are used to obtain the similarity value output. Lastly, simulated annealing optimization is used to obtain the best result from the model. All entities involved in the process could be represented in class forms. They configured high-levelly in class diagram then (Figure 3). Here, the classes MedicalWaste, MedicalWasteTreatment, and Decision are principle classes of the model. Also, all parts which run model's activities are developed in five components. The interconnection among components is scientifically described in Figure 4 (component diagram). Each component has a unique characteristic of task to do. They collaborate to produce proper and objective decision.

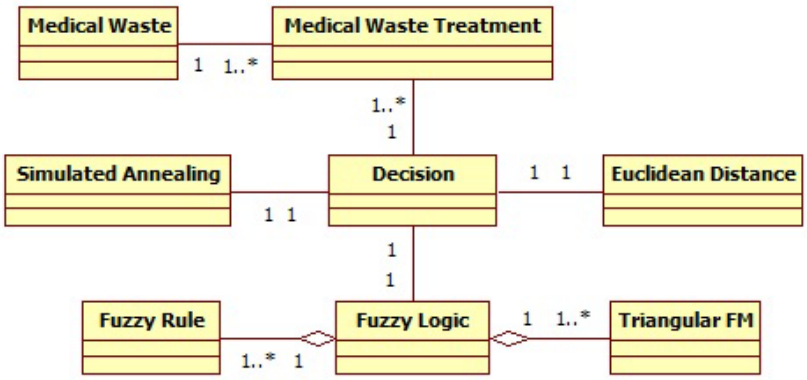

FIGURE 3. Class diagram for the constructed model

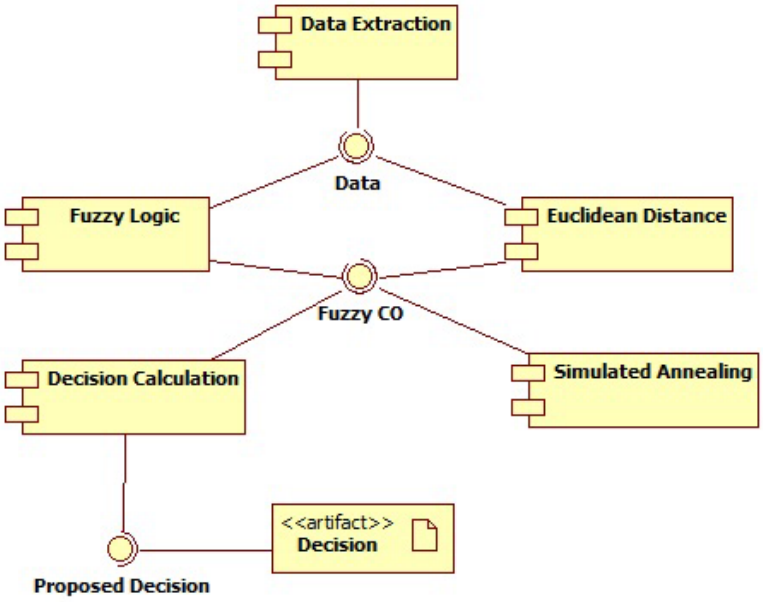

FIGURE 4. Component diagram for the constructed model

The model was constructed by considering eight selected parameters: environmental impact, land need, treatment effectiveness, waste type, waste reduction, treatment cost, land need and waste volume. Environmental impact, land need, treatment effectiveness and waste type parameters are practically judged by experts. Treatment cost and land need use relative value calculation and lastly waste volume uses similarity measure. They are processed through triangular membership function in Figure 5 and the mathematical

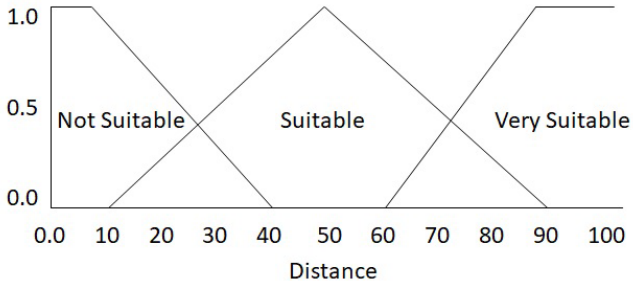

FIGURE 5. Fuzzy triangular membership function for appropriateness justification between parameters and decision alternatives

statement in Equation (1) where $DeVa$ is a defuzzified value, x_i represents an ith fuzzy value, and y_i symbolizes an ith linguistic variable's centroid value.

$$DeVa = \frac{\sum \mu(x_i y_i)}{\sum \mu(x_i)} \tag{1}$$

Schematically, the parameters are handled via the scheme developed by [8]. The scheme is operated to produce the decision. In [8], three styles of technique are methodically operated; fuzzy logic (for fundamental parameterizing), Euclidean distance (to outline the fitness fee), and simulated annealing optimizing concept (to locate the first-class fee of decision). The [8]'s version is constructed with the aid of thinking about six selected parameters: environmental impact, land need, remedy effectiveness, waste type, treatment cost, and waste quantity [3-5,7,20-22]. First four parameters are practically judged by using two expert judgement. On the opposite hand, the alternative parameters are one-to-one measured based totally on evaluation and empirical data.

Fundamentally, all parameters included in new constructed model are spoken to in class MedicalWaste, and a wide range of treatment are hypothetically produced from class Treatment (classes Incinerator, Autoclave, Microwave, Mechanical Processing & Chemical Disinfection, Vitrification, Landfill). For typically choosing the best treatment, class Simulated Annealing (with strategy for Simulated Annealing optimization inside) shows up. The strategy for Euclidean separation count is spoken to by class Euclidean Distance and acknowledgment of fuzzy logic method is presented in class Fuzzy Logic (it is class of fuzzy membership function), where tasks fuzzification and defuzzification are structured in. The main difference from this research with the previous research is that this research takes on more medical waste type and medical waste treatment.

For realizing the model, numerical data fully operated to validate it. Figure 6 describes the result of calculation modelling result for the general waste. The calculation used in this model is presented in formula below. Environmental Impact (ωp) is in Equation (2), Effectivity (εp) (3), Land Need (τp) (4), Volume Reduction (γp) (5) where, i is the ith treatment strategy (there are six treatment strategies), $n = 5$ (there are five types of waste), $\omega p \in \mathbb{R}$, and $0.00 \leq \omega p \leq 1.00$. Capital Cost and Operating Cost are operated using relative value method using Equation (6).

Land Need is similarly processed using relative value. Then, $\overline{c}_{ij}$ is converted to cp_i via fuzzy logic process, where $\overline{c}_i$ is a land need point for the ith treatment strategy, $cp_i \in \mathbb{R}$, and $0.00 \leq cp_i \leq 1.00$, $\overline{\eta}_i$ is also converted to $\overline{\eta}p_i$ via fuzzy logic process, where $\overline{\eta}_i$ is a land need point for the ith treatment strategy, $\overline{\eta}p_i \in \mathbb{R}$, and $0.00 \leq \overline{\eta}p_i \leq 1.00$. Furthermore, for measuring parameter waste volume (vp), similarity value calculating is performed. Here similarity is analogized via distance value. That is why here the similarity value is calculated via calculating distance between waste capacity (c_1) VS treatment strategy's optimal capacity (c_i). It is easily calculated via Equation (9), where ρ_i is converted via fuzzy logic to become vp_i, and δ_i is a distance between the ith waste's volume and the ith

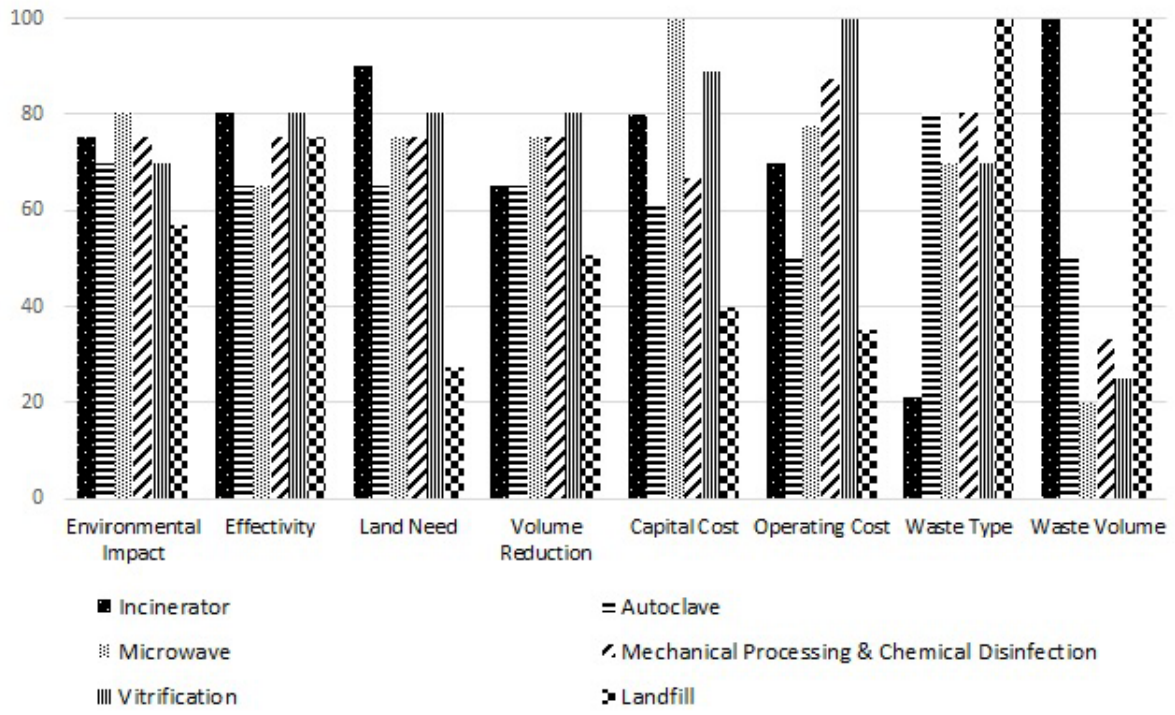

FIGURE 6. Calculation modeling result for the general waste

strategy's optimal capacity, ρ_i is a distance point for the ith treatment strategy, $vp_i \in \mathbb{R}$, and $0.00 \leq vp_i \leq 1.00$. Decision of treatment strategy is decided by calculating decision value (DV), where DV_i is a decision value for the ith treatment strategy, and $a, \ldots, f$ are parameter coefficients judged by experts. DV itself is a value aggregated from all parameters' value and their coefficients. Here, Eco-DSM is able to generate DVs. They are 72.71 for incinerator, 63.40 for microwave, 70.44 for autoclave, 71.01 for mechanical processing & chemical disinfection, 74.35 for vitrification and 60.68 for landfill. It can be concluded that the proposed decision of treatment strategy is vitrification.

$$\omega p_i = \frac{\sum_{j=1}^{n} \omega p_{ij}}{n} \tag{2}$$

$$\varepsilon p_i = \frac{\sum_{j=1}^{n} \varepsilon p_{ij}}{n} \tag{3}$$

$$\tau p_i = \frac{\sum_{j=1}^{n} \tau p_{ij}}{n} \tag{4}$$

$$\gamma p_i = \frac{\sum_{j=1}^{n} \gamma p_{ij}}{n} \tag{5}$$

$$\overline{c}_{ij} = \frac{c_{\min}}{c_{ij}} \tag{6}$$

$$\overline{\eta}_{ij} = \frac{\eta_{\min}}{\eta_{ij}} \tag{7}$$

$$\delta(c_1, c_i) = \sqrt{c_1 - c_i} \tag{8}$$

$$\rho_i = \frac{1}{\delta_i} \tag{9}$$

$$DV_i = a\omega p_i + b\varepsilon p_i + c\tau p_i + d\gamma p_i + e\eta p_i + fcp_i \tag{10}$$

Indeed, we did an extended research from [8] did. the extended research was done by adding several more medical waste treatments methods, i.e., mechanical processing and

chemical disinfection, vitrification and landfill. The model was then conducted to suggest the most mathematically objective decision, with combination of fuzzy logic, Euclidean distance and simulated annealing optimization. The model can be realized for solving big number of data. The constructed model can propose the best/proper quantitative alternative decision to select the medical waste treatment strategy. Definitive input is taken from expert's justification for parameters and empirical data related from type and waste quantity. The empirical data itself was taken from one hospital in Pontianak, Indonesia.

5. **Conclusion and Further Works.** With the increase in health services in hospitals, health centers, clinics or laboratories, the production of medical waste will also increase. Medical waste is a hazardous waste because of the infectious content in it. Therefore, medical waste management must get serious attention. Treatment for treating various types of medical waste, in choosing or determining the most suitable and best treatment is not easy. There are several variables that must be considered to choose the best processing.

This study, in constructing the Eco-DSM, uses variables including the type of waste, the amount of waste, cost, environmental impact, land need, volume reduction and the effectiveness of the treatment using the fuzzy logic and the Euclidean methods. These results are obtained from the calculation of expert judgment on the variables of each alternative and empirical data.

The combination study with other domain is possibly open for further works. More domain can be used or adopt the constructed model for further research. Also, more data is able to enrich the model test.

Acknowledgment. We would like to thank Bina Nusantara University who has supported our studies and research, particularly to Bina Nusantara Graduate Program, Master of Computer Science; also, to all hospital entities involved (doctor, staffs, etc.).

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