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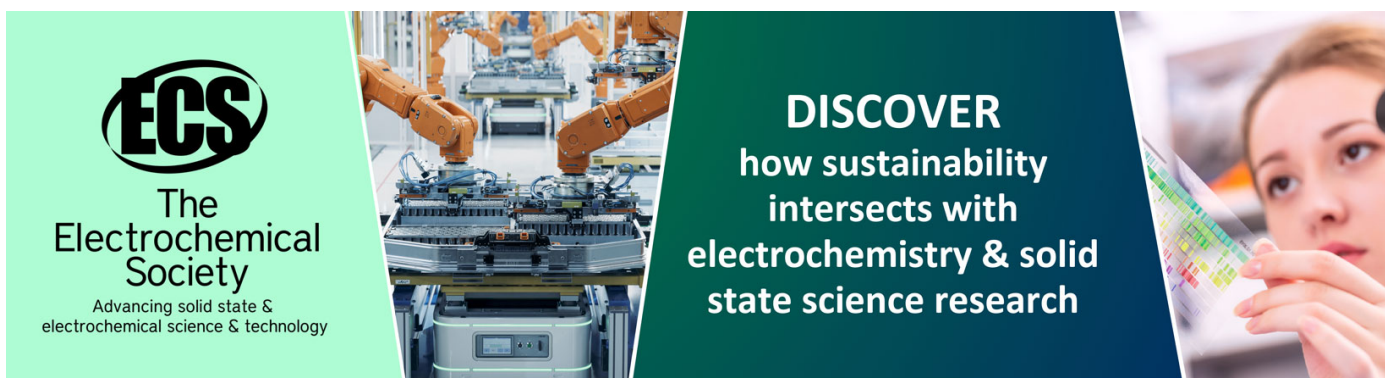
Fuzzy eco-DSM for treating medical waste

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Fuzzy eco-DSM for treating medical waste

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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. One of them should be used to treat medical waste by considering six selected parameters and three decision alternatives. In this study, environmental issue is main concerned aspect that the constructed model consequently becomes ecological DSM (eco-DSM). Three main methods are operated to construct the model; they are fuzzy logic, Euclidean distance, and full-factorial optimization methods. The model is analysed and designed via object oriented method. Lastly, the study shows simulation results based on empirical data of medical waste from one class 'A' state hospital in Jakarta, Indonesia.

Keywords: ecological, environmental, decision support model, medical waste, fuzzy logic

1. Introduction

A specific approach to handle medical waste is realistically necessitated. It is triggered by high negative risks and hazardous unique characteristics of waste [1]. The medical waste itself is yielded via medical activities, e.g. medical diagnosis; human and animal medical treatment; medicine, radioactive and medical tools usage; and medical surgery activities [2]. Moreover, it is theoretically separated into two categories; clinical and non-clinical waste, both liquid and solid wastes. Specifically medical solid waste could be categorized thru sharps, anatomical, infectious, cytotoxic, pharmacy, chemical wastes, etc. [3].

A model which is feasibly functioned to manage the waste is a decision support model (DSM). With its capability and distinctiveness, and also by considering several identifiable parameters, the model is capable for recommending the decision maker to decide an objective decision, purposely in treating the waste.

Talking on the order of DSM, numerous researchers have previously selected this issue as the main idea in their researches. For examples; [4], [5], [6], [7], [8], [9], [10], and [11]. [4] developed DSM based on simulated annealing (SA) optimization to place fast food restaurant which has exclusive features. Through using fuzzy logic to parameterize the parameter based on expert judgment, SA operated to optimize the decision from lots of decision alternatives. The model can suggest the best location for realizing the fast food restaurant. [5] built a DSM for supporting the decision maker to make a decision in renovating and rehabilitating the mosques. In this study, the fuzzy logic and hill-climbing optimization methods are technically functioned and the model can rank the most crucial mosque to be renovated primarily.

Furthermore, [6] proposed a new method implemented in DSM configuration to learn the patient's ASA score (patient's pre-anaesthetic scale). The score is practically benefitted to support decision



maker in making a patient surgery decision. The accurate decision rationally has positive consequence to reduce both anaesthetic risks and mortality percentage. [7] merged three methods (i.e. interpretive structural modelling, analytical network processing, and fuzzy logic) to build a DSM for assessing a collaboration performance. The level of partnership performance index was created by model as a fundamental judgment to choose a decision. [8] also created a DSM for delivering a vigorous decision making for automatic railway level crossing. By benefitting fuzzy logic control method, the model was operated to save the operation time, to avoid any accidental facilities, and to remove human errors. Additionally, [9] built a DSM to support the decision maker in choosing the best facility. In this study, the best means condition associating with energy saving and facility improvement program. It was conducted in elementary school in South Korea. [10] constructed a DSM too to obtain a better productivity of maritime automobile terminals. The productivity measured was connecting to the combination among internal transport, exit truck gate operation, and wagon manipulation. At last, [11] established a DSM as well for particularly renovation that is able to advise a rational policy for renovating and reconstructing organizations' facilities.

Therefore, the paper portrays an ecological DSM (eco-DSM) that operated to support decision maker to practically treat medical waste, which has economic and environmental impacts. One hospital in Jakarta (Indonesia) and one types of medical waste (infectious) were selected as a research object in this study. The section of introduction of the paper is followed by sections Related Works, Research Methodology, Results and Discussion, and Conclusion and Further Works.

2. Related works

Indeed, the researches discussing medical waste as a main issue were many. This issue tried to be observed from various fields and science domains. For example what [12] did. They conducted a research to measure toxic polychlorinated dibenzo-p-dioxins (PCDDs) / polychlorinated dibenzofurans (PCDFs) in stack gas of medical waste incinerators. It was coming from 19 medical waste incinerators in South Korea. Also with [13] who was doing study to generate and compose the solid medical waste for six months at seven medical microbiology labs. It was concluded that on average 35% of the total waste was hazardous waste.

Moreover, in cleaner production field, [14] academically performed a study concerning medical waste. The study aimed to quantify a technology of medical waste treatment. By using two central methods (i.e. life cycle assessment and life cycle costing), [14] quantified the impacts of three types of medical waste disposal scenario; i.e. pyrolysis, steam sterilization, and chemical disinfection. The study showed that two scenarios steam sterilization and chemical disinfection have highest environmental and lowest economic influences. In the same field, [15] initiated an application to assess a risk of infectious medical waste management. Here, the biggest health institution of South-East Europe was learnt as a study object. In assessing the risk, by considering three properties (i.e. functional, qualitative, and quantitative), they operated the method fault tree analysis (FTA). They successfully concluded that the analysis indicated the fundamental occurrences which when mitigated have the highest effect on the failure risk of the whole medical waste management system.

3. Research methodology

Fundamentally, the study was conducted thru three main stages (Figure 1); preliminary study, situational analysis, and model construction. Mainly, literature study relates to the topic (via a systematic review) was done in the first stage (the preliminary study stage). Here, a lot of papers which are connecting to topics medical waste, decision support model, and environmental aspects were reviewed systematically. It aims to scientifically understand the topic deeper, know well the position of the research among others (state of the art), and discover the research gap. Then, the research object was explored more in the next stage Situational Analysis. In the second stage, field study was realistically performed and also the experts were occupied to evaluate the parameters (via expert judgement). Lastly, the model was constructed in the last stage (the model construction stage) by collaborating all previous results. In the last stage, at least five scientific methods were operated officially.

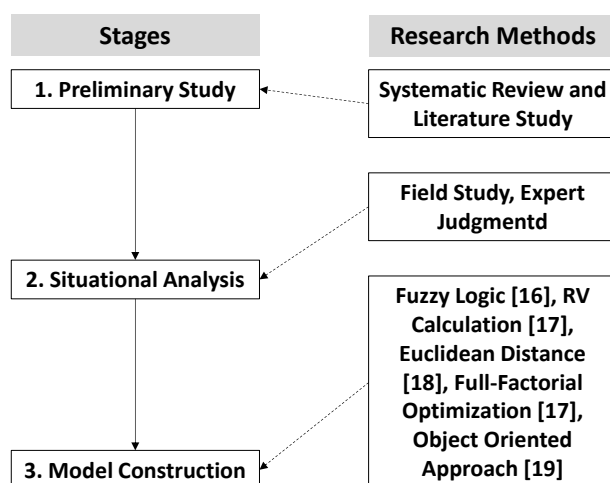


Figure 1. Research stages.

The method fuzzy-logic [16] is a fundamental method operated in this study. Two types of medical waste parameter and four types of medical waste treatment parameter are numerically processed thru this method. Particularly to judge four parameters (parameters number 1 until 4, they respectively are environmental impact, land need, treatment effectiveness, and waste type; see Figure 2.), three experts are occupied; where the waste type is divided into two types: sharp and infectious. The experts involved to evaluate the properness between parameter and three types of decision alternatives (types of treatment strategy) via the triangular membership function of fuzzy illustrated in Figure 3. The experts' evaluation (where E1, E2, and E3 respectively denote the expert 1, expert 2, and expert 3) for parameters in fuzzy value is illustrated in Table 1. The, it was converted to Table 2 via equation (1); where DV is a defuzzified value, X_i represents an i th fuzzy value, and Y_i symbolizes an i th linguistic variable's centroid value. Two other parameters (number 5 is treatment cost and number 6 is waste quantity) are one-to-one measured based on analysis and empirical data thru exclusive fuzzy triangular membership function.

$$DV = \frac{\sum_{i=1}^n (X_i \times Y_i)}{\sum_{i=1}^n X_i} \quad (1)$$

Additionally, for next calculation, last two parameters are treated by using relative value (RV) calculation [17], and then, specifically for waste quantity, the method Euclidean distance [18] is used to analyse the relevance between waste quantities with type of waste treatment. For evaluating all options of medical waste empirical data, the method full-factorial optimization [17] is theoretically functioned. The method logically checks and evaluates all possibilities of empirical data. Subsequently, the best alternative must be detected. Finally, to design the model, several diagrams (e.g. class and use-case diagrams) based on the concept of object oriented approach [19] are benefitted.

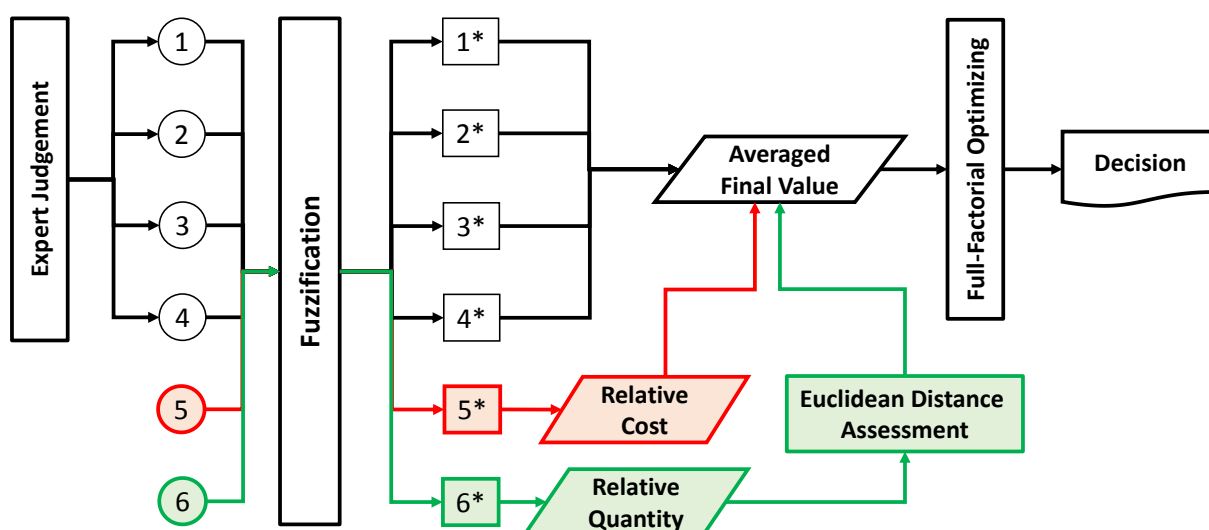


Figure 2. High level scheme for decision making.

4. Result and discussion

4.1. Constructed model

Schematically, the parameters are treated thru the scheme configured in Figure 2. The scheme is operated to produce the decision. Here, three types of method are methodically operated; fuzzy logic (for fundamental parameterizing), Euclidean distance (to define the fitness value), and full-factorial optimizing concept (to find the best value of decision). The model is constructed by considering six selected parameters; environmental impact ([20], [21], and [22]), land need ([21]), treatment effectiveness ([20], [21], [23], and [24]), waste type ([20]), treatment cost ([20], [21], [22], [23], [24], and [25]), and waste quantity ([26]); they are respectively presented by number 1 until 6. First four parameters are practically judged by three experts. On the other hand, the other two parameters are one-to-one measured based on analysis and empirical data.

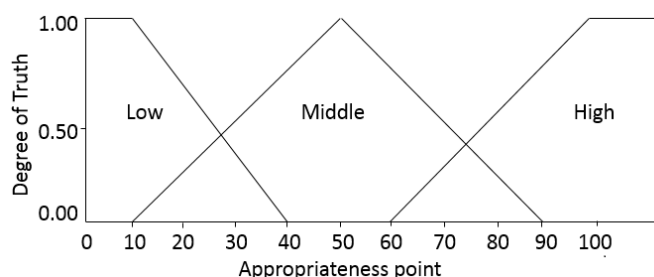


Figure 3. Fuzzy triangular membership function for appropriateness justification between parameters and decision alternatives.

Obviously, the fuzzy value coming from experts' judgement for the first four parameters (environmental impact, land need, treatment effectiveness, and waste type; where there are two types of waste: sharp and infectious) is exhibited in Table 1. It was processed thru triangular membership function in Figure 3 and the mathematical statement in equation (1), and the result is represented in Table 2.

All captured data (as crisp inputs) are processed through fuzzy logic process (fuzzification) to obtain crisp outputs (fuzzified values; they are represented by starred number in Figure 2.). Before converted to final value (via average calculation), particularly parameters treatment cost (red line) and waste quantity (green line) are treated differently. They are firstly converted to relative value and relative and then distance / fit value (via Euclidean distance calculation) respectively. By using concept of full-factorial optimizing, the best value of decision is conclusively revealed.

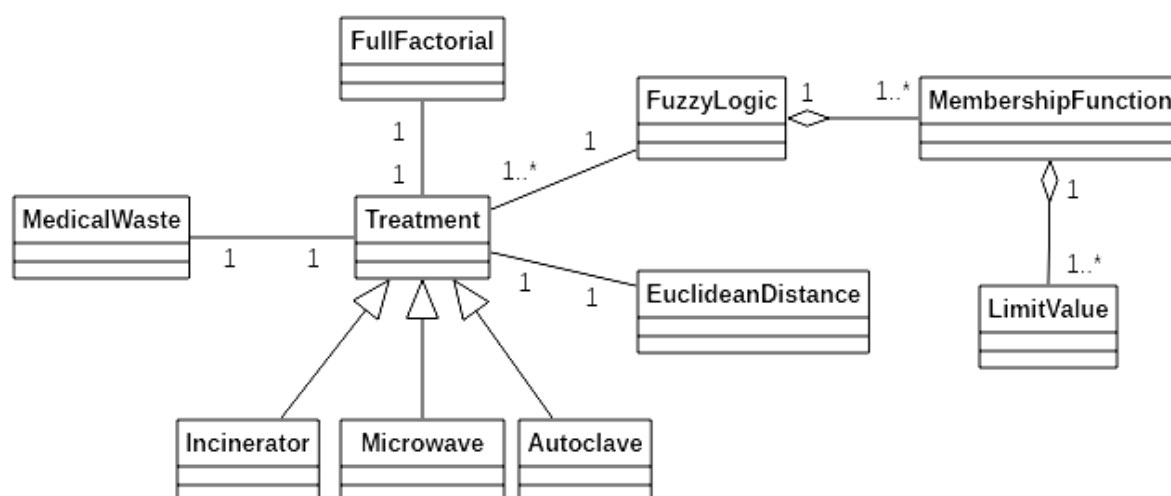


Figure 4. Class diagram for the constructed model.

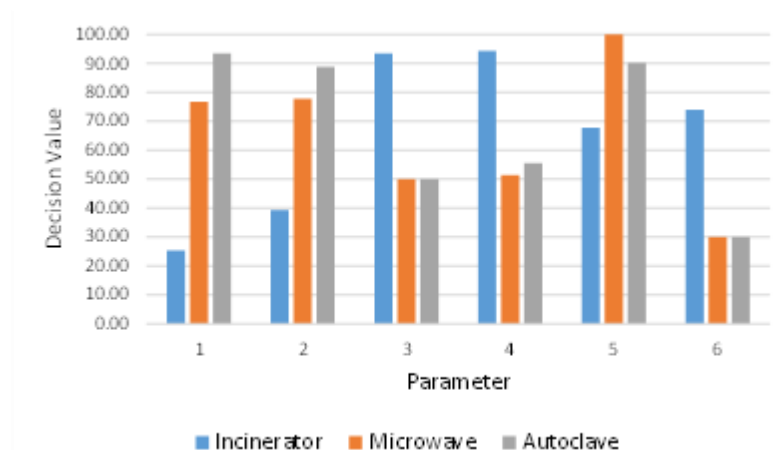


Figure 5. Calculation modeling result for infectious waste.

The class diagram is a high level structure to depict a connection among entities or parts (in object or class representation) of the constructed model. The interconnection is described via the class diagram in Figure 4. Here, the classes *MedicalWaste* and *Treatment*, indeed, are main classes of the model. All parameters included are represented in class *MedicalWaste*, and all types of treatment are theoretically generated from class *Treatment* (classes *Incinerator*, *Microwave*, and *Autoclave*). For normally selecting the best treatment, class *FullFactorial* (with method of full factorial optimization inside) appears. The method of Euclidean distance calculation is represented by class *EuclideanDistance* and realization of fuzzy logic method is represented in class *FuzzyMF* (it is class of fuzzy membership function), where operations fuzzy-fication and de-fuzzy-fication are designed in.

For realizing the model, numerical data operated to validate it. Figure 5 describes the result of calculation modelling for infectious waste with quantity 420kgs. The model generates decision values 69.03 for incinerator, 57.80 for microwave, and 72.26 for autoclave. It can be concluded that the proposed decision of treatment strategy for infectious medical waste (420kgs) is autoclave.

Table 1. The experts' evaluation for parameters.

Parameters	Alternatives	Fuzzy Value E1	Fuzzy Value E2	Fuzzy Value E3
Environmental impact	Incinerator	0.67 low 0.25 middle	0.67 low 0.25 middle	0.33 low 0.50 middle
	Microwave	0.25 middle 0.50 high	0.75 high	1.00 middle
	Autoclave	0.25 middle 0.50 high	0.75 high	0.75 high
Land need	Incinerator	0.33 low 0.50 middle	0,75 middle	0,33 low 0,50 middle
	Microwave	0.25 middle 0.50 high	0.50 middle	0.25 middle 0.50 high
	Autoclave	0.75 high	0.25 high	0.75 high
Treatment effectiveness	Incinerator	0.25 middle 0.50 high	1.00 high	0,75 high
	Microwave	0.75 middle	0.75 middle	1.00 middle
	Autoclave	0.50 middle 0.25 high	0.75 middle	1.00 middle
Sharp waste	Incinerator	0.25 middle 0.50 high	0.75 high	1.00 middle
	Microwave	1.00 middle	1.00 middle	0.67 low 0.25 middle
	Autoclave	0.75 middle	0.25 middle 0.50 high	1.00 middle
Infectious waste	Incinerator	0.25 middle 0.50 high	0.75 high	1.00 high
	Microwave	0.25 middle 0.50 high	0.75 middle	0.67 low 0.25 middle
	Autoclave	0.50 middle 0.25 high	0.75 middle	0.75 middle

4.2. Discussion

We similarly did a research with what [14] did. They quantified a technology of medical waste treatment. They computed the impacts of three types of medical waste disposal scenario; i.e. pyrolysis, steam sterilization, and chemical disinfection. In their study, two main methods (i.e. life cycle assessment and costing) are scientifically operated, and dominantly environmental factors are taken into account. Nevertheless, we academically conducted it thru using a constructed computer model that is able to suggest the most mathematically objective decision; with method combination of fuzzy logic, Euclidean distance, and full-factorial optimization. In our study, three types of parameters (i.e. ecological, economy, and waste treatment technology) are considered. Also, our model can be realized in solving a big number of data. Technologically, our constructed model is configured in Figure 6. with use-case diagram; where, it consists of two human actors (Expert and staff of Installation of Sanitation), one system actor (Medical Waste Management Information System), and four types of use-case (Extracting Data, Parameterizing, Making Decision, and Reporting).

Completely, the constructed model is able to propose the proper/best quantitative alternative decision to select the treatment strategy for treating medical waste. Definitive input are coming from experts' justification for parameters and empirical data relating to type and quantity of waste. The empirical data itself was practically extracted from one class 'A' state hospital in Jakarta, Indonesia.

Table 2. The parameters' de-fuzzified value of experts' evaluation.

Parameter	Alternatives	E1	E2	E3
Environmental impact	Incinerator	21.00	21.00	34.00
	Microwave	80.30	100.00	50.00
	Autoclave	80.30	100.00	100.00
Land need	Incinerator	50.00	50.00	34.00
	Microwave	83.30	66.70	83.30
	Autoclave	100.00	66.70	100.00
Treatment effectiveness	Incinerator	83.30	100.00	100.00
	Microwave	50.00	50.00	50.00
	Autoclave	66.70	50.00	50.00
Sharp waste	Incinerator	83.30	100.00	50.00
	Microwave	50.00	50.00	21.00
	Autoclave	50.00	83.30	50.00
Infectious waste	Incinerator	83.30	100.00	100.00
	Microwave	83.30	50.00	21.00
	Autoclave	66.70	50.00	50.00

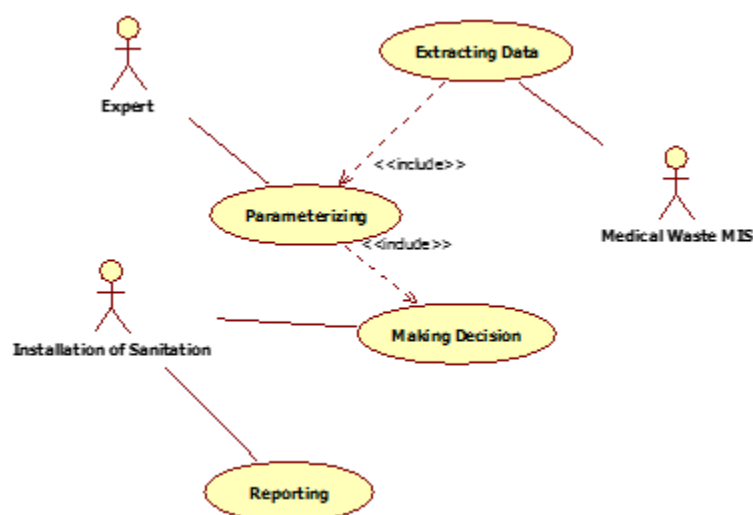


Figure 6. The usecase diagram of the constructed model.

5. Conclusion and further works

The specified effort in management of medical waste treatment is realistically demanded. It is influenced by unsafe characteristics of the waste itself. Here, a decision support model (precisely an ecological decision support model) to select the most proper treatment strategy of medical waste was academically constructed. It is able to quantitatively advise the most treatment strategy taken by hospital. In this study, six types of parameter are rationally taken into account; and three main approaches are benefited to develop the model, they are fuzzy-logic, Euclidean distance, and full-factorial optimization. As a final point, the method object oriented is used to design the model. Then, the simulation result which was conducted by acquiring three experts' assessment data and empirical data explaining type and quantity of medical waste quantitatively recommended autoclave as the most appropriate treatment strategy to select.

Finding the other potential parameters should be studied deeply. The further study is able consider such other parameters, e.g. government rules, hospital resource, etc. The parameters are possibly able to enrich the model performance in solving the problem.

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