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FUZZY MULTI CRITERIA DECISION MAKING - A MATHEMATICAL MODEL FOR WASTE MANAGEMENT

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ABSTRACT

Fuzzy Multi Criteria Decision Making is an efficient planning methodology used for illustrating the trade-off between environmental and economic parameters and for assisting in the selection of a compromise solution. For Waste Management, every Municipal Corporation has to consider several constraints (conflicting) under Fuzzy environment. Hence most of the selection of parameters cannot be given precisely and the evaluation data of various subjective criteria and the weights of the criteria are usually expressed in linguistic terms by the decision makers. Fuzzy Multi Criteria Decision Making Model would yield a good enough compromise solution in terms of the aspiration levels given to the objective and the constraints.

Keywords—*Waste management, Fuzzy Multi Criteria Decision Making etc.*

I. INTRODUCTION of WASTE

Waste has been a major environmental issue everywhere since the industrial revolution. Besides the waste we create at home, school and other public places, there are also those from hospitals, industries, farms and other sources. Humans rely so much on material things and they all (almost) end up as waste.

Waste is items we don't need and discard. Sometimes there are things we have that the law requires us to discard because they can be harmful. Waste comes in infinite sizes—some can be as small as an old toothbrush, or as large as the body of a school bus. Everyone creates waste, although some people are very environmentally conscious and do a very good job in creating less waste and managing the rest. Others are pretty horrible and have created huge environmental problems for the people and animals living there.

II. TYPES OF WASTE

Generally, waste could be liquid or solid. Both of them could be hazardous. Liquid and solid type of waste can also be grouped into organic, re-usable and recyclable waste.
Let us see some details below:

Liquid type:
Waste can come in non-solid form. Some solid waste can also be converted to a liquid waste form for disposal. It includes point source and non-point source discharges such as storm water and wastewater. Examples of liquid waste include wash water from homes, liquids used for cleaning in industries and waste detergents.

Solid type:
Solid waste predominantly, is any garbage, refuse or rubbish that we make in our homes and other places. These include old car tires, old newspapers, broken furniture and even food waste. They may include any waste that is non-liquid.

Hazardous type:
Hazardous or harmful waste are those that potentially threaten public health or the environment. Such waste could be***inflammable*** *(can easily catch fire),* ***reactive*** *(can easily explode),****corrosive*** *(can easily eat through metal) or* ***toxic*** *(poisonous to human and animals)*. It is required by law to involve the appropriate authority to supervise the disposal of such hazardous waste. Examples include fire extinguishers, old propane tanks, pesticides, mercury-containing equipment (e.g, thermostats) and lamps (e.g. fluorescent bulbs) and batteries.

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Organic type:
Organic waste comes from plants or animals sources. Commonly, they include food waste, fruit and vegetable peels, flower trimmings and even dog poop can be classified as organic waste. They are biodegradable (this means they are easily broken down by other organisms over time and turned into manure). Many people turn their organic waste into compost and use them in their gardens.

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Recyclable type:
Recycling is processing used materials (waste) into new, useful products. This is done to reduce the use of raw materials that would have been used. Waste that can be potentially recycled is termed "Recyclable waste". Aluminum products (like soda, milk and tomato cans), Plastics (grocery shopping bags, plastic bottles), Glass products (like wine and beer bottles, broken glass), Paper products (used envelopes, newspapers and magazines, cardboard boxes) can be recycled and fall into this category.

III. SOURCES OF WASTE

Municipal sources of waste:
This includes trash or garbage from households, schools, offices, market places, restaurants and other public places. They include everyday items like food debris, used plastic bags, soda cans and plastic water bottles, broken furniture, grass clippings, product packaging, broken home appliances and clothing.

Medical/Clinical sources of waste:
Medical/clinical waste, normally refers to waste produced from health care facilities, such as hospitals, clinics, surgical theaters, veterinary hospitals and labs. They tend to be classified as hazard waste rather than general waste. Items in this group include surgical items,pharmaceuticals, blood, body parts, wound dressing materials, needles and syringes

Agricultural sources of waste:
Typically, this is waste generated by agricultural activities. These include horticulture, fruit growing, seed growing, livestock breeding, market gardens and seedling nurseries.
Waste items in this group include empty pesticide containers, old silage wrap, out of date medicines and wormers, used tires, surplus milk, cocoa pods and corn husks.

Industrial sources of waste:
Since the industrial revolution, the rise in the number of industries manufacturing glass, leather, textile, food, electronics, plastic and metal products has significantly contributed to waste production. Take a look at the things in your home, every item there was probably manufactured and possibly, waste was produced as a result.

Construction/demolition sources of waste:
Construction waste is that resulting from the construction of roads and building. Sometimes old buildings and structures are pulled down (demolished) to make space for new ones. This is particularly common in old cities that are modernizing. This is called demolition waste.
Waste items include concrete debris, wood, earth, huge package boxes and plastics from the building materials and the like.

Electronic sources of waste:
This is waste from electronic and electrical devices. Think of DVD and music players, TV, Telephones, computers, vacuum cleaners and all the other electrical stuff in your home. These are also called e-waste, e-scrap, or waste electrical and electronic equipment (WEEE)
Some e-waste (like TV) contains lead, mercury, cadmium, and brominated flame retardants. These are harmful to humans and the environment.

It is therefore important that the right authorities ensure the proper disposal of such waste.

ISSN 2348 – 8034
Impact Factor- 3.155

IV. HOW IS WASTE TREATED AND DISPOSED OFF?

Waste management simply means the collection, transport, processing or disposal, managing and monitoring of waste materials to minimize its' consequences on humans and environment. There are several methods of managing all the various types of waste. Some of these methods cause additional harm to the environment, but not doing anything is not an option.
Let us see below two common ways of managing waste:

Incineration method of waste management:
This simply means burning waste. This method is common in countries with limited landfill space. Incineration chambers can be small for domestic use, but ther are large ones for municipal use as well. It is great for treating waste with contamination (like those from hospitals) and hazardous waste from factories, but the method produces too much carbon dioxide. Modern incineration processes are more efficient and release less dioxin than home fireplaces and backyard barbecues. This method is very common in Denmark, Germany and the Netherlands. This method is effective, but expensive.

Sanitary Landfills as waste disposal:
Generally, this term means a large piece of land away from living places where all the waste from a town is deposited. But there is more to landfills. Proper landfill management involves sorting out all the waste (waste separation), and sending only the waste that cannot be recycled and composted to the site.

Proper landfills are also lined at the bottom to minimize the leakage of soil pollutants and other toxins from getting into the water table. This method is effective, but expensive and difficult.

Proper waste management is not cheap, but it is something we all have to get involved and discuss it. The effect of not getting involved can be catastrophic to our health and environment

V. MULTI CRITERIA DECISION MAKING

Planning for Waste Management using multi-criteria analysis has attracted the attention of decision makers for a long time. The methods can provide solutions to increasing complex management problems. Traditional single criteria decision making is normally aimed at maximization of benefits with minimization of costs. These methods provide better understanding of inherent features of decision problem, promote the role of participants in decision making processes, facilitate compromise and collective decisions and provide a good platform to understand the perception of models' and analysts' in a realistic scenario. The methods help to improve quality of decisions by making them more explicit, rational and efficient. Negotiating, quantifying and communicating the priorities are also facilitated with the use of these methods.

In a real-world decision situation, there are typically multiple (conflicting) criteria that need to be evaluated in making decisions. Cost or price is usually one of the main criteria. Some measure of quality is typically another criterion that is in conflict with the cost. In purchasing a car, cost, comfort, safety, and fuel economy may be some of the main criteria we consider. It is unusual that the cheapest car is the most comfortable and the safest one. In a service industry, customer satisfaction and the cost of providing service are two conflicting criteria that would be useful to consider. Multiple-criteria decision-making (MCDM) considers multiple criteria in decision-making environments.

In our daily lives, we usually weigh multiple criteria implicitly and we may be comfortable with the consequences of such decisions that are made based on only intuition. On the other hand, when stakes are high, it is important to properly structure the problem and explicitly evaluate multiple criteria. For any Municipal Corporation, in making the decision of whether to dispose the waste or not, and where to dispose it, there are not only very complex issues involving multiple criteria, but there are also many stakeholders who are deeply affected from the consequences.

Structuring complex problems well and considering multiple criteria explicitly lead to more informed and better decisions. There have been important advances in this field since the start of the modern multiple-criteria decision-making discipline in the early 1960s. A variety of approaches and methods, many implemented by

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Impact Factor- 3.155

specialized decision-making software, have been developed for their application in an array of disciplines, ranging from politics and business to the environment and energy.

MCDM is concerned with structuring and solving decision and planning problems involving multiple criteria. The purpose is to support decision-makers facing such problems. Typically, there does not exist a unique optimal solution for such problems and it is necessary to use decision-makers preferences to differentiate between solutions.

VI. MEANING OF SOLUTION

"Solution of a MCDM Problem" can be interpreted in different ways. It could correspond to choose the "best" alternative from a set of available alternatives (where "best" can be interpreted as "the most preferred alternative" of a decision-maker). Another interpretation of "solving" could be choosing a small set of good alternatives, or grouping alternatives into different preference sets. An extreme interpretation could be to find all "efficient" or "nondominated" alternatives.

The difficulty of the problem originates from the presence of more than one criterion. There is no longer a unique optimal solution to a MCDM problem that can be obtained without incorporating preference information. The concept of an optimal solution is often replaced by the set of nondominated solutions. A nondominated solution has the property that it is not possible to move away from it to any other solution without sacrificing in at least one criterion. Therefore, it makes sense for the decision-maker to choose a solution from the nondominated set. Otherwise, she/he could do better in terms of some or all of the criteria, and not do worse in any of them. Generally, however, the set of nondominated solutions is too large to be presented to the decision-maker for his final choice. Hence we need tools that help the decision-maker focus on his preferred solutions (or alternatives). Normally one has to "tradeoff" certain criteria for others.

VII. BASIC CONCEPTS OF MCDM

Before discussing in detail about the MCDM, let me introduce the following terminologies which are necessary for the development of the theory involved.

Objectives

An objective is the reflection of the desire of the decision maker and generally indicates the direction in which he/she should strive to achieve his goal. For example, one may wish to minimize the cost involved in the operation, whereas other may be interested in maximizing the customer satisfaction and the third may like to reduce machine time, etc.

Aspiration Level

An aspiration level is a specific numerical value assigned to the objective according to the desire of the decision maker. Typically an aspiration level is expressed in terms of a measure of the achievement of an objective.

Goal and Deviation

An objective in conjunction with an aspiration level is termed as GOAL. Not all aspirations can be achieved and not all restrictions may be strictly satisfied. Consequently, we shall encounter deviations from the goals. Normally we seek to minimize the deviations.

Decision Space and Objective Space

If we have n number of decision variables $x_1, x_2, x_3, ..., x_n$ and k number of objectives $z_1, z_2, z_3, ..., z_k$, which are functions of the decision variables $x_1, x_2, x_3, ..., x_n$. One can represent the decision variables $x_1, x_2, x_3, ..., x_n$ and the objectives $z_1, z_2, z_3, ..., z_k$ as vector "X" and "Z" respectively. It

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represents the set of all n-tuples and k-tuples of real numbers in Euclidean n-space and Euclidean k-space respectively.

VIII. ILLUSTRATIONS OF THE DECISION AND CRITERION/ OBJECTIVE SPACES

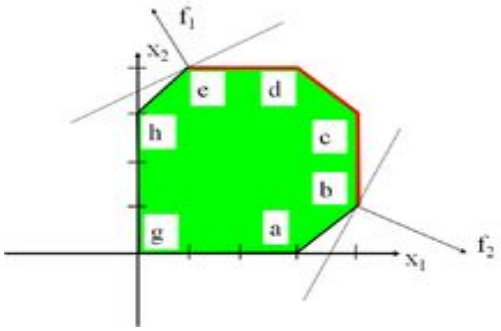
The following two-variable MCDM problem in the decision variable space will help to demonstrate some of the key concepts graphically.

$$\text{Max } f_1(\mathbf{x}) = -x_1 + 2x_2$$
$$\text{Max } f_2(\mathbf{x}) = 2x_1 - x_2$$

subject to

$$x_1 \leq 4$$
$$x_2 \leq 4$$
$$x_1 + x_2 \leq 7$$
$$-x_1 + x_2 \leq 3$$
$$x_1 - x_2 \leq 3$$
$$x_1, x_2 \geq 0$$

Figure as below Demonstrate the decision space



In this Figure, the extreme points "e" and "b" maximize the first and second objectives, respectively. The red boundary between those two extreme points represents the efficient set. It can be seen from the figure that, for any feasible solution outside the efficient set, it is possible to improve both objectives by some points on the efficient set. Conversely, for any point on the efficient set, it is not possible to improve both objectives by moving to any other feasible solution. At these solutions, one has to sacrifice from one of the objectives in order to improve the other objective.

IX. WHY A FUZZY –MCDM?

Fuzzy sets were introduced by Zadeh (1965) as an extension of the classical notion of sets. This idea is used in many **MCDM** algorithms to model and solve fuzzy problems.

The classic MCDM methods generally assume that all criteria and their respective weights are expressed in crisp values and, thus, that the rating and the ranking of the alternatives can be carried out without any problem. In a real-world decision situation, the application of the classic multi-criteria evaluation methods may face serious practical constraints from the criteria perhaps containing imprecision or vagueness inherent in the information. Due to the no availability and uncertainty of information as well as the vagueness of human feeling and recognition, like ‘‘equally’’, ‘‘moderately’’, ‘‘strongly’’, ‘‘very strongly’’, ‘‘extremely’’ and a ‘‘significant degree’’, it is relatively difficult to provide exact numerical values for the criteria, make an exact evaluation and convey the feeling and recognition of objects for decision makers. Hence most of the selection parameters cannot be given precisely and the evaluation data of the alternative’s suitability for various subjective criteria and the weights of the criteria are usually expressed in linguistic terms by the decision makers.

X. MATHEMATICAL MODEL OF FUZZY MULTI CRITERIA DECISION MAKING

ISSN 2348 – 8034
Impact Factor- 3.155

Usually, a multi criteria decision making problem can be expressed as below:
Maximize

$$Z_1 = C^1 X = c_1^1 x_1 + c_2^1 x_2 + c_3^1 x_3 + \ldots + c_n^1 x_n$$
$$Z_2 = C^2 X = c_1^2 x_1 + c_2^2 x_2 + c_3^2 x_3 + \ldots + c_n^2 x_n$$
.
.
$$Z_k = C^k X = c_1^k x_1 + c_2^k x_2 + c_3^k x_3 + \ldots + c_n^k x_n$$

Subject to

$$a_{11}x_1 + a_{12}x_2 + a_{13}x_3 + \ldots + a_{1n}x_n \geq b_1$$
$$a_{21}x_1 + a_{22}x_2 + a_{23}x_3 + \ldots + a_{2n}x_n \geq b_2$$
.
.
$$a_{m1}x_1 + a_{m2}x_2 + a_{m3}x_3 + \ldots + a_{mn}x_n \geq b_m$$

Where $x_1, x_2, x_3, \ldots, x_n \geq 0$.

In summation notation they can be expressed as:

$$MaxZ_k = \sum_{j=1}^{n} c_j^k x_j, k = 1,2,3,\ldots,k,$$

Subject to $\sum_{j=1}^{n} a_{ij} x_j \geq b_i, i = 1,2,3,\ldots,m,$

and $x_j \geq 0, j = 1,2,3,\ldots,n..$

In matrix form, the above problem can be given as:

$$MaxZ = C\underline{X}$$

Subject to $A\underline{X} \geq \underline{B}$

and $\underline{X} \geq 0$.

Assuming that we have a fuzzy goal for each of the objective functions and the constraints in the MCDM Problems, the fuzzy version of the MCDM is given as below:

Find $\underline{X}$

Such that $C\underline{X} \lesssim z_0$

$A\underline{X} \gtrsim b_0$

$\underline{X} \geq 0$.

Where z_0 and b_0 are the aspiration levels and the symbol " $\approx$ "indicate the fuzzification. In the fuzzy formulation the strict optimization of the standard formulation is replaced with a gradual attainment of aspiration levels (z_0 , b_0). This principle was introduced by Bellman and Zadeh (1970), which makes use of (i) the properties of the membership function, and (ii) the operators for combining membership functions with the logical connectives. The solution thus obtained is a good enough compromise solution in terms of the aspiration levels given to the objective and the constraints.

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XI. CONCLUSION

It is recognized that human judgment on qualitative criteria is always subjective and thus imprecise. Fuzzy set theory introduced by Zadeh in 1965 can just solve the problem and it play a significant role in this kind of decision situation. The combination of MCDM methods and fuzzy set theory has been applied in many systems. The model could handle the vagueness and imprecision of input data, and help the decision makers to find out the optimal solution.

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