Fuzzy-TOPSIS for Appropriate Site Selection for Establishing a Thermal Power Plant

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By

SOUMYA PANIGRAHI

Roll No. 110ME0216

Under the Guidance of

Prof. SAURAV DATTA

NATIONAL INSTITUTE OF TECHNOLOGY
ROURKELA 769008, INDIA

NATIONAL INSTITUTE OF TECHNOLOGY
ROURKELA 769008, INDIA

Certificate of Approval

This is to certify that the thesis entitled **Fuzzy-TOPSIS for Appropriate Site Selection for Establishing a Thermal Power Plant** submitted by ***Sri Soumya Panigrahi*** has been carried out under my supervision in partial fulfillment of the requirements for the Degree of ***Bachelor of Technology*** in ***Mechanical Engineering*** at **National Institute of Technology**, **NIT Rourkela**, and this work has not been submitted elsewhere before for any other academic degree/diploma.

Dr. Saurav Datta

Assistant Professor

Department of Mechanical Engineering

National Institute of Technology, Rourkela

Rourkela-769008

Date:

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Soumya Panigrahi

Abstract

Thermal Power Plant (TPP) is one of those discoveries that have changed the daily life of everybody on the real world. Now TPP is playing a vital role in real world due to population growth, modernization of industrial sector and agricultural sections. To meet the demand of modern world regarding thermal power, expansion of TPP must be considered. The appropriateness of chose site for power plant influences the measure of created vitality, power plants processing, expense of power generation, temperate advancement, environment and transmission (loss of power). Accordingly, in site determination process for a TPP it is important to painstakingly think about the specialized issues, as well as its effect on nature's turf, economy and close neighborhood groups. The tried and true methodologies to TPP site determination have a tendency to be less successful in managing the loose or dubious nature of the phonetic appraisal. Under numerous circumstances, the qualities of the judgemental criteria are frequently loosely characterized for the top management. To conquer this situation, Fuzzy Multi-Criteria Decision Making (FMCDM) methodology is proposed. In this reporting, we exhibit a multi-criteria choice making methodology for site determination of TPP under fractional or inadequate data. The proposed approach basically furnished in two steps. In the first step, the criteria for the location of TPP is found out. In the second step, decision-makers give qualitative ratings as well as weights to the alternate choices verses the proposed criteria. Fuzzy-TOPSIS (*Technique for Order of Preference by Similarity to Ideal Solution*) is applied to generate overall value of evaluation for the optimal choice. Finally a case empirical research is adapted to fruitful the proposed approach.

***Keywords*:** Thermal Power Plant (TPP), Fuzzy Multi-Criteria Decision Making (FMCDM), Technique for order preference by similarity to Ideal Solution (TOPSIS)

Contents

1. Introduction

Thermal energy is a vital variable in all parts of improvement, including, nature's turf, horticulture, and socio-economy when all is said in done. In world, because of colossal populace development, mechanical advancement, rural area, urbanization and changes in everyday life style of individuals, and so forth the interest for warm vitality has been expanding ceaselessly. To react to this expansion in the interest for warm vitality adequately, it is important to foresee the force utilization for the impending years and to get ready for the vital improvement in the force preparation. TPP as the wellsprings of force supply are the most urgent some piece of the force framework. Essential, existing force plants ought to be enhanced and new plants ought to be secured. The development of a TPP is normally exceptionally costly and prolonged and has escalated consequences for nature's domain and on all parts of both individuals life and socio-investment region. Therefore, extensive studies are required before the set-up of a TPP. The most vital parameters that should be first defined are the type of the TPP, its capacity and the most suitable location for it. In eastern part of India large amount of coal has been exist. Therefore, some new TPP is set-up to development of power generation. The location of a TPP has significant effects on the efficiency of power generation, the cost of power production, transmission and its environmental brunt, therefore the site selection of TPP should be done very carefully. Here Fig. 1 indicated the expected power required for operating different sector of India by 2020. Fig. 1 also indicated to meet demand of different sector regarding power, new power plant set up is very essential.

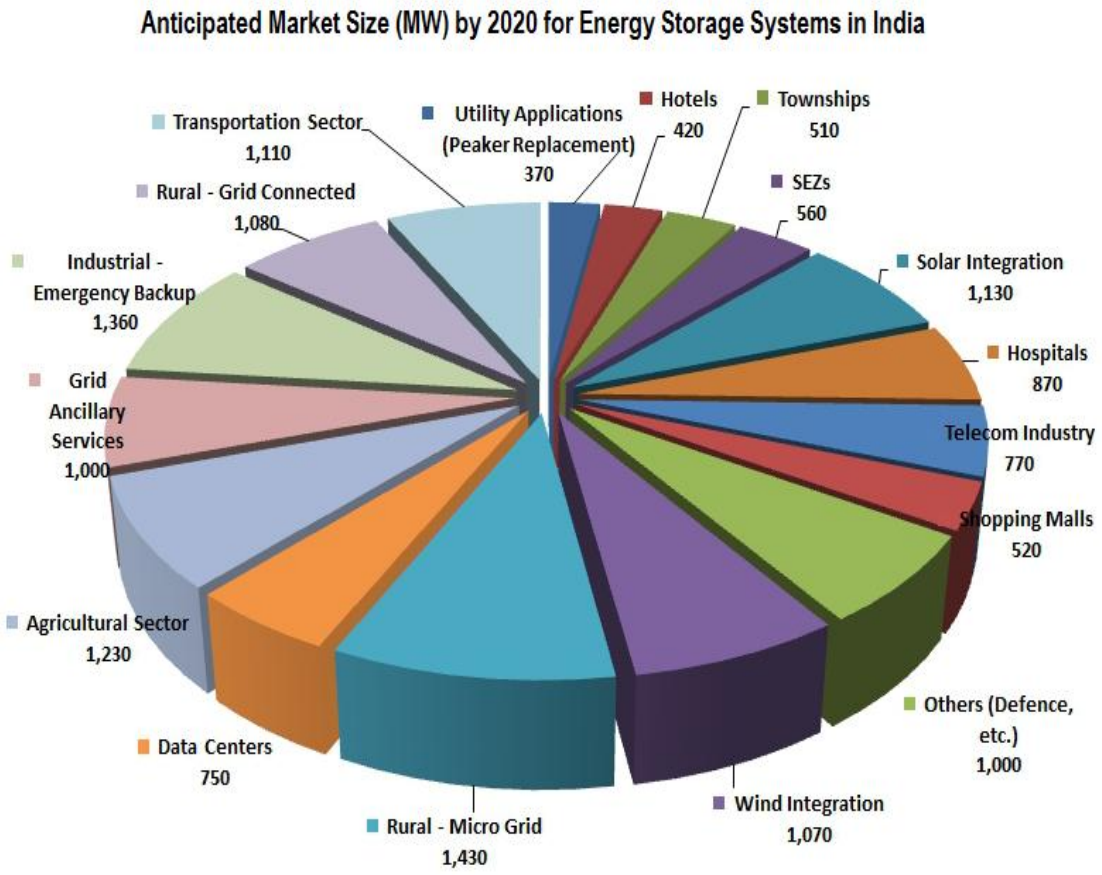


Fig. 1 Anticipated Market Size (MW) by 2020 for Energy Storage System in India (**Source**: www.renewindians.com)

As per **press information bureau, Government India**, focus for power era is settled on a yearly premise. As against the power generation focus of 930 BU for the year 2012-13, 911.65 BU has been achieved, which is 98% of the target. The general power era in energy utilities in the country and what's more import from Bhutan since the begin of ninth Plan is as under:

YEAR	**GENERATION (BU)**
2004-05	**587.4**
2005-06	**617.5**
2006-07	**662.52**
2007-08	**704.5**
2008-09	**723.8**
2009-10	**771.6**
2010-11	**811.1**
2011-12	**876.9**
2012-13	**911.65**

BU: Billion Units

The aggregate All India Installed Capacity of electric producing stations as on 31st March, 2013 was 2,23,343.60 MW and the demand was 1,35,453 MW.

Power area has become absolutely over the eleventh Plan period. It enlisted a development rate of 3.96% in 2012-13. The crest shortfall in the year 2012-13 was 9% against the setback of 10.6% in the year 2011-12. The choice to include era limit of 88,537 MW, import 82 Million Tons of coal, decrease in transmission and conveyance misfortunes and so forth is relied upon to conquer any hindrance between top request and crest met.

According to above information, we analysed still now India has been importing power from neighbour country. In other side, for growth of different sector (Fig. 1) power generation capacity must be increase. So we must emphasis to setup new power plant to meet the country demand. In India, coal based thermal power has been the principle wellspring of producing power, and would essentially keep on remaining the primary creating hotspot for taking care without bounds power demand. This is because of the way that expansive coal saves in the nation give a primed and conservative asset and guarantee power security.

2. Literature Review

Presently-a-days TPP area determination is an imperative vital choice. Barda et al. (1990) proposed TPP area issue as multi-criteria choice issue and connected ELECTRE III system to select best area. Ramos et al. (2000) acknowledged monetary dangers while selecting site for TPP. Valadan Zoej et al. (2005) utilized Geographic Information System (GIS) approach for selecting suitable area for development of TPP. Feng (2010) utilized unpleasant sets to acquire weight for quantitative and qualitative data and proposed a multi target model to adjust the two objectives of expense least and productivity most extreme for ideal site choice of TPP.

Multiple attribute decision making (MADM) strategy is customarily used to understand diverse decision making and determination issues. This approach ordinarily requires the pioneers to give qualitative and quantitative evaluations to choosing the execution of each elective with respect to each standard, and the relative vitality of appraisal criteria concerning the general target. Technique for order preference by similarity to an ideal solution (TOPSIS), known as a traditional MADM system, has been produced by (Hwang and Yoon, 1981) for tackling the MADM issue. On the off chance that the appraisal qualities are known to have different sorts of unclearness/imprecision or objectiveness, then the established choice making systems are not helpful for such issues. We realize that TOPSIS is one of the known traditional MCDM systems, may give the premise to creating site choice of TPP models that can adequately manage these properties. It bases upon the approach that the select elective ought to have the most brief separation from the Positive Ideal Solution and the most remote from the Negative Ideal Solution.

Chen (2001) highlighted another MADM approach for determining the DC area choice issue under fuzzy situations focused around a stepwise positioning technique. Liang and Wang (1991) proposed a fuzzy MCDM technique for the office site determination, where the appraisals of different elective areas under different subjective criteria and the weights of all criteria are surveyed in phonetic terms spoke to by fuzzy numbers. Zangeneh, Jadid and Rahimi-Kian (2011) highlighted a static fuzzy multi-target model to focus the ideal size, area and likewise the best possible engineering of circulated era station. Brown and Gibson (1972) proposed a quantified model that ordered the goal and subjective variables vital to the particular area issue being tended to as; discriminating, target, and subjective.

Kuo, Chi and Kao (1999) recommended a choice help supportive network by incorporating fuzzy set hypothesis and the AHP in selecting a site for another comfort store. Therefore, Kuo, Chi and Kao (2002) created a choice help supportive network for placing new comfort stores by incorporating the fluffy AHP and a simulated neural system. Liang and Wang (1991) proposed a calculation for office site determination focused around progressive structure investigation, where the appraisals of different elective areas under different subjective criteria and the weights of all criteria are surveyed in semantic terms spoke to by fuzzy numbers. Chou, Chang and Shen (2008) introduced another fuzzy straightforward added substance weighting framework, for taking care of plant area determination issues by utilizing destination/subjective characteristics under choice-production conditions. Kahraman, Ruan and Dogan (2003) utilized four fuzzy multi-property bunch choice-production approaches in assessing office areas. These methodologies were reached out to select the best office area elective by considering quantitative and qualitative criteria.

To settle the aforementioned approach in MCDM, another coordinated technique focused around TOPSIS is proposed. The fundamental tenet of the TOPSIS technique is that the choose elective ought to have the most brief separation from the perfect result and the most distant separation from the negative perfect result. Tavakkoli- Moghaddam and Mousavi (2011) said that, TOPSIS system proposes two reference focuses; in any case, it doesn't recognize the relative significance of the separations from these focuses. Besides, the standardized values by vector standardization in the TOPSIS strategy may rely on upon the evaluation unit the normalized value.

In this work, we display a multi criteria choice making methodology to site determination of TPP under indeterminate (fuzzy) circumstances. Whatever is left of the report is composed as takes

after: The first step includes choice of criteria for site determination of TPP. In this study, 21 criteria were utilized for site choice of TPP. The second step includes designation of linguistic evaluations to the 21 criteria and the potential decisions for each of the criteria by the pioneers or experts. The alternative evaluations for each of the criteria are taken from given etymological table. The phonetics terms are then changed over to fuzzy trapezoidal numbers. By then, fuzzy TOPSIS is associated with total the criteria and alternative the rankings to produce an overall score for site choice of TPP. The most noteworthy score is chosen as the best elective for TPP area.

3. The Generalized Trapezoidal Fuzzy Numbers

Fuzzy sets and fuzzy logic are effective scientific apparatuses utilized for demonstrating dubious frameworks. A fuzzy set is an augmentation of a crisp set. A crisp set just permits full membership or non membership, while fuzzy sets permit partial membership. The hypothetical fundamentals of fuzzy set hypothesis are outlined by (Chen, 2000).

A fuzzy set $\tilde{A}$ in a universe of discourse X is portrayed by a membership function $\mu_{\tilde{A}}(x)$ which connects with each element x in X a real number in the interval [0, 1]. The function value $\mu_{\tilde{A}}(x)$ is termed the grade of membership of x in $\tilde{A}$. A trapezoidal fuzzy number can be defined as $\tilde{A}=(a_1,a_2,a_3,a_4;w_{\tilde{A}})$ as shown in Fig. 2 and the membership function $\mu_{\tilde{A}}(x): R\to[0,1]$ is defined as follows:

$$\mu_{\tilde{A}}(x)=\begin{cases}\dfrac{x-a_1}{a_2-a_1}\times w_{\tilde{A}}, & x\in(a_1,a_2)\\ w_{\tilde{A}}, & x\in(a_2,a_3)\\ \dfrac{x-a_4}{a_3-a_4}\times w_{\tilde{A}}, & x\in(a_3,a_4)\\ 0, & x\in(-\infty,\ a_1)\cup(a_4,\ \infty)\end{cases}$$

Here, $a_1 \le a_2 \le a_3 \le a_4$ and $w_{\tilde{A}} \in (0,1)$

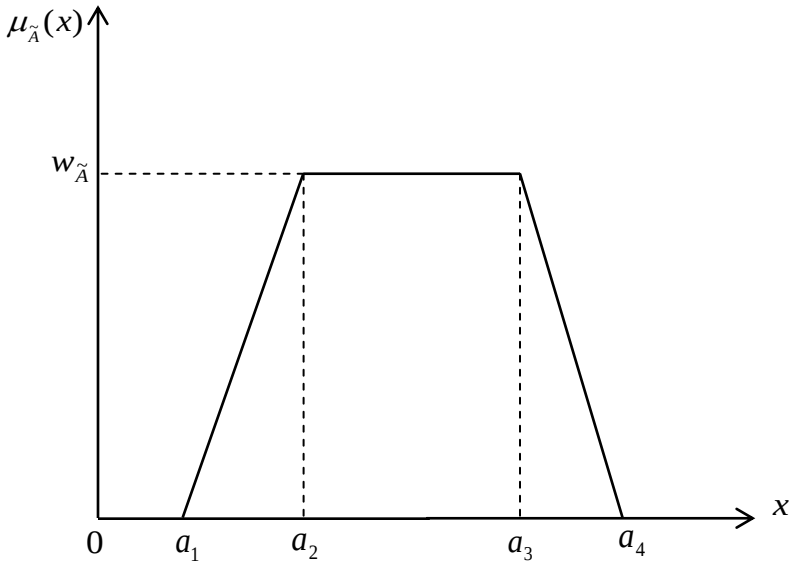


Fig. 2: Trapezoidal fuzzy number $\tilde{A}$

Suppose that $\tilde{a} = (a_1, a_2, a_3, a_4; w_{\tilde{A}})$ and $\tilde{b} = (b_1, b_2, b_3, b_4; w_{\tilde{B}})$ are two trapezoidal fuzzy numbers, then the operational rules of the trapezoidal fuzzy numbers $\tilde{a}$ and $\tilde{b}$ are shown as follows:

$$\tilde{a} \oplus \tilde{b} = (a_1, a_2, a_3, a_4; w_{\tilde{A}}) \oplus (b_1, b_2, b_3, b_4; w_{\tilde{B}}) =$$

$$(a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4; \min(w_{\tilde{A}}, w_{\tilde{B}})) \quad (1)$$

$$\tilde{a} - \tilde{b} = (a_1, a_2, a_3, a_4; w_{\tilde{A}}) - (b_1, b_2, b_3, b_4; w_{\tilde{B}}) =$$

$$(a_1 - b_4, a_2 - b_3, a_3 - b_2, a_4 - b_1; \min(w_{\tilde{A}}, w_{\tilde{B}})) \quad (2)$$

$$\tilde{a} \otimes \tilde{b} = (a_1, a_2, a_3, a_4; w_{\tilde{A}}) \otimes (b_1, b_2, b_3, b_4; w_{\tilde{B}}) =$$

$$\tilde{a} \otimes \tilde{b} = \left(a_1 \times b_1,\ a_2 \times b_2,\ a_3 \times b_3,\ a_4 \times b_4; \min\left(w_{\tilde{A}}, w_{\tilde{B}}\right)\right) \quad (3)$$

$$\tilde{a} / \tilde{b} = \left(a_1, a_2, a_3, a_4; w_{\tilde{A}}\right) \Big/ \left(b_1, b_2, b_3, b_4; w_{\tilde{B}}\right)$$

$$= \left(a_1 / b_4, a_2 / b_3, a_3 / b_2, a_4 / b_1; \min\left(w_{\tilde{A}}, w_{\tilde{B}}\right)\right) \quad (4)$$

4. Site Selection Criteria of TPP

The main step includes choice of criteria for site determination of TPP. In this study, 21 criteria were utilized for site determination of TPP. These criteria were chosen from West Coast Regional Carbon Sequestration Partnership Annual Business Meeting by (Ghose, 2008). The meanings of the criteria are summarized as takes after:

Site Selection criterion	Explanation
Land Availability or CCS Footprint	**Industrial forests** Industrial forests are a profitable merchandise. Site assessment ought to refer the timberland assets of the site and adjacent grounds, and the impacts of industry development and funtioning on these assets. For the most part, more alluring locales have reduced effects on these assets. **Land acquisition** Each one location will have one of a kind area procurement prerequisites and impacts. By and large, locales that have easier land securing expenses and oblige shorter procurement times are more alluring. **Land use compatibility** Ordinarily, dynamic or empty industrial terrains may be more good and urban private terrains may be less perfect with force plants. For the most part, destinations that are more perfect with present and arranged area utilization are much attractive, same as those where the industry would agree to presently area use regulations. **Recreational areas** Recreational regions are open or personal grounds of investment and quality, including parks, chasing grounds, and designated diversion terrains. They could be dislodged by another plant or harmed by clamor or

	stylish effects. For the most part, locales that reduces affects on recreational regions, and are close fewer and less intensely utilized recreational territories, are more attractive.[https://psc.wi.gov/]
Seismic Stability	Seismic stability alludes to a power plant capability to withstand a earthquake. A seismic stability assessment takes a gander at how plant will perform throughout a substantial tremor and looks at the impacts of seismic risks, for example, shaking and surface issue crack. Power plant must withstand serious quakes with negligible mishappening to avoid overtopping and ensure life and property. Earthen plants may droop or twist under extreme seismic tremor shaking. Analysis decides the conduct of plants and whether they oblige retrofit ventures.
Floodplain	It's essential to decrease the importance for surge harm and industry closure. Plans ordinarily place discriminating supplies over the 100-year surge level. Non-basic shares of plant frameworks (e.g., streets and cradle zones) beneath the 100-year level could be raised, barriers, or generally ensured. For the most part, locales totally out of the floodplain or destinations with room to spot significant plant gear out of the floodplain are favored over locales where real supplies might be placed in the floodplain. [https://psc.wi.gov/]
Weather	The site must have the capacity to help development and production in a manner that reduces disintegration, sedimentation, and flow of toxins by storm water spillover to waters of the state. Locales that posture issues for spillover administration (profoundly erodible soils, soak slants, and so forth.) are less attractive. Furthermore, administration of the floodwaters themselves may be a worry to nearby inhabitants. For the most part, destinations with no wetlands or no potential for antagonistic wetland impacts are alluring. Destinations with minor wetlands or restricted potential for wetland impacts are more attractive than locales with bigger regions of wetlands and more huge potential wetland impacts. Locales with amazing wetlands or substantial practical wetlands are less alluring. [http://en.wikipedia.org]
Existing Site Hazards	Site geography can influence development expenses and ecological effects. The characteristics of most investment are the general site geography (ground incline), soil sorts and profundities, and profundity to groundwater. These components influence the measure of earthwork obliged and plant configuration prerequisites, for example, establishment and channeling establishment. By and large, locales with moderately level geology are favored over moving knolls or soak grades. Soil sorts with great weight-bearing limit are favored over soils with poor building attributes. Ideal destinations additionally have satisfactory groundwater profundities to help plant development and stay away from shallow water table issues.
Existing Land Use	Existing Land utilization may have brought about site pollution. It's essential to think about the presence of site tainting and the expenses of cleanup in the choice of force plant locales. Locales without ecological defilement are more attractive to the engineer. Emptied modern

	destinations may introduce open doors for siting force plants when these locales are not debased with unsafe materials or generally entangled by existing concerns. Then again, tainted locales may give a "win-win" circumstance if site cleanup could be fulfilled while as of now giving a financially savvy-site good fortune.
Restricted Air Space	Elected rules confine the stature of structures closeairports. These rules may cause inconveniences for plant structures like towers or stacks. It's basic to watch that a site can take after Federal Aviation Administration (FAA) and other airspace standards. For the most part, locales at more amazing separations from landing strips and designated clear zones are alluring, as are destinations balanced from runway arrangements. Engineers should likewise think about conceivable confinements on the area of force plant-related landfill locales close runways. [http://en.wikipedia.org]
Cultural Resources	Cultural Resource , likewise alluded to as social legacy administration or rescue archaic exploration, is the review for and documentation of archeological destinations induced by the need to look at locales before they are decimated by development or characteristic fiascos. Area 106 of the National Historic Preservation Act of 1966 made the first lawful prerequisites for archeological examination and site alleviation on federally supported undertakings, however state, tribal, and city governments frequently have laws obliging designers to study, record, and potentially uncover or keep away from archeological stays, contingent upon their noteworthiness. Samples of CRM are studies led along open utility easements and migration of gravesites. CRM archeologists regularly work under tight due dates that make weight to keep away from the more systematic methodology of scholarly archeologists.
Threatened and Endangered Species	**Protected species** Ensured species are state or federally recorded extraordinary, debilitated, or imperiled organization or creature species and their territories, along with uncommon living groups. By and large, locales where no secured species are influenced are better alluring than destinations where ensured species are found in off-site ranges influenced by processes or where ensured species coexist in the cushion range. Destinations where ensured species are spotted in the dynamic site region are less attractive. **Wildlife and natural lands** Developing an era office and helper structures could have an immediate impact on natural life, environment, and terrains with great qualities of regular environmental groups. Destinations with next to zero impact on untamed life and regular grounds are more alluring than locales with more huge effects on these characteristic assets. **Wildlife impacts from operation** There are critical processing effects on untamed life and natural life territory furthermore impacts from air and water quality changes because of the ignition process. They incorporate effects identified with fuel, for example, coal dust overflow, effects identified with cooling, for example,

	fish found in cooling water frameworks or the release of warmed cooling water into ponds, or different effects, for example, winged creature mortality from striking structures or new power lines. Touchy destinations are those that help more amazing untamed life use (vicinity to great living space, movement courses, nourishment assets, and so forth.). Notwithstanding, offices can likewise be intended to improve environment by fusing naturalized cradle territories or utilization of cooling water for fishponds. [https://psc.wi.gov/]
Proximity to Public Access Areas	General awareness about health impacts connected with presentation to attractive fields has centered consideration on electric offices. Despite the fact that exploratory vulnerability perseveres, open concerns ought to be recognized in sitting offices. Data of investment incorporates how attractive fields close to the force plant and cohorted lines will change. For the most part, more attractive destinations are such having no increments in EMF on existing lines (reductions are more alluring). Locales that oblige latest ways may be more attractive if lesser individuals are laid open to the EMF processed by the line. Power line courses that reduce the amount of living arrangements, schools, and so forth., inside the range of impact may be more alluring. **Operational odors** Smell is a specific concern to close-by occupants. There is open enthusiasm toward comprehension the reason and quality of any smells and knowing the separation these smells may travel past the plant site limit. Force plant destinations that have nonexistent or frail smells with a short separation of development are more attractive than locales with offensive smells that move past the site limits. **Traffic safety** There are ordinarily two classifications of traffic security concern. One is the expansion in neighborhood traffic, with a specific enthusiasm toward truck and rail movement. Alternate is the potential for cooling tower float to cause misting or icing of roadways contiguous a plant. By and large, locales with minimal potential for bringing about activity expansions or clogging and almost no potential for effect by cooling tower float may be more alluring. [https://psc.wi.gov/]
State/Local Environmental Requirements	**Air quality** This model is utilized to assess the potential for unfriendly effects on the non-human parts of the earth, for example, vegetation, amphibian life, untamed life, building materials, and so forth. A few contaminations may have long haul, total effects on vegetation and untamed life, or help the disintegration of building materials, for example, limestone. Numerous dangerous contaminations, for example, overwhelming metals, unfavorably influence the strength of natural life and plants. The levels of these overwhelming metals develop in tissues, bringing on incessant harmful impacts on wellbeing, propagation, and different capacities. A hefty portion of these are likewise passed on through the natural pecking order, packing all the more in savage creatures, for example, birds and

	walleye. It is imperative to think about the vicinity of naturally delicate assets in the region influenced by the force plants' discharges. The site affectability might depend additionally on: collaborations around the sorts and convergances of emanations; the capability of control innovations to fundamentally diminish these outflows; the modes of scattering of these contaminations once they are in nature's domain; their determination and bioaccumulation potential; and what is thought about their unfavorable consequences for fish, untamed life, plants and materials. **Groundwater impacts - recharge, discharge, quantity, and quality** Groundwater effects incorporate the effect of a power plant and offices upon groundwater topology (level of water under the ground along with streams) and the nature of groundwater. Potential force plant impacts incorporate (1) the effect of utilization of water on the underground level and the amount of groundwater accessible for different utilization and (2) the degree of clearing and different exercises that diminish the permeation of water into the ground. Unfriendly consequences for nearby aquifers that help wetlands, springs, and stream base stream ought to be minimized. Destinations with more constrained groundwater assets on or close to the site may be less attractive. The vicinity of groundwater-ward assets on or close to the site ought to additionally be acknowledged. **Waste minimization, recycling, or reuse** There may be site-particular open doors to diminish the volume and quality of fluid or robust waste prepared in producing electric force, and to reuse or reuse those waste items that are handled. These may incorporate nearby commercial enterprises or projects that could utilize power era waste items or force plant offices that decrease squanders going to landfills by utilizing the squanders as fuel. **Wastewater treatment discharge** The capacity of waters to get wastewater medicine releases and assimilate them fluctuates. The waters must have the ability to assimilate compound contrasts, for example, included biocides or contrasts in ph or physical contrasts in hotness without unfavorably influencing sea-going life and environment. Locales with close-by water assets that have a substantial capacity to assimilate water medication release without unfriendly impacts are alluring. Slightest attractive are those locales where water assets have practically no capacity to retain water medicine release without unfavorable impacts. **Wetlands** It is preferable to have locations without any wetlands with negative impacts. Locations with small wetlands with less chance of adverse impacts can be more suitable than those with huge wetlands with more chances of adverse effects. Locations with superior wetlands or enormous working ones are never wanted for. [http://en.wikipedia.org]
Proximity to Class I	The term perceivability, when utilized as a part of the connection of

Visibility Areas	beautiful vistas at obligatory Federal Class I territories, alludes to the clarity with which far off articles are seen. Perceivability is influenced by poison fixations, the review edge, relative moistness, cloud aspects, and other physical variables, for example, color differentiation between items. Without the impacts of artificial air contamination, a regular visual extent might be about 140 miles (225 km) in western ranges and 90 miles (145 km) in eastern zones. The barometrical toxins that regularly influence perceivability exist as vaporizers (minor particles scattered circulating everywhere). An airborne molecule is made of robust and/or fluid particles that are held together by intermolecular or glue constrains and go about as a solitary unit. Hazes and fogs are normal cases of pressurized canned products framed basically from water vapor. Particulate matter alludes to the non-water particles that structure strong or fluid pressurized canned products in the environment. The following area talks about the five most regular particulate matter species, arranged as per compound investigates. The particulate matter being fewer than 2.5 microns (PM2.5) have a composition of various constituents, a variety of analysis has been conducted to categorize the important factors to visibility impairment: • sulfate, • nitrate, • organic carbon, • elemental carbon, and • crustal material. [https://epa.gov]
Proximity to Tribal Lands	**Tribally owned lands** are of three kinds: Trust land – The local groups possess and profitable prospects though the legal functioning is controlled by the government. Restricted fee land - The local groups hold the legal functioning having certain restrictions imposed on them. Fee land purchased by tribes - The tribe secures legitimate funtioning under particular permited power. Charge area possessed by a tribe outside the limits of a reservation is not subject to lawful limitations against estrangement or encumbrance, nonattendant any exceptional circumstances. The law is not clear whether such limitations apply to charge arrive inside the limits of a reservation. [https://teeic.anl.gov] The Department of Agriculture orders prime farmland as land that holds prime farming soils for yield generation. These farmlands are viewed as a significant asset. Site studies ought to address the vicinity of prime farmland on the site and the impacts of plant development and operation on this farmland. Different farmlands, in spite of the fact that not considered "prime," might likewise be paramount to think about throughout siting (e.g., exceptionally gainful inundated grounds or less beneficial fields that are fundamental for neighborhood homesteads to survive). By and large, locales that utilization or contrarily influence critical agrarian area may be less attractive.
Access to Cooling Water	Numerous power plant advances use water from lakes, streams, civil water utilities, or groundwater. Surface water is utilized for plant cooling

	and groundwater is utilized for plant procedures. By and large, the vicinity of sufficient and usable water assets at or close to a site is favored over locales with remote, deficient, or low-quality water assets. Locales with no contending water utilization are for the most part liked to destinations with numerous employments. The utilization of water by a force plant can possibly influence the nearby water supply and the nature's turf. To meet water supply prerequisites, force plants may utilize groundwater wells, the nearby city supply, or both. This utilization may put an overwhelming load on the neighborhood framework, bringing down water yields from close-by wells. It might likewise not influence the framework or adjacent wells, or it may upgrade the nearby framework. For the most part, locales where plant water utilization will have restricted water supply impacts or those that help overhauls of neighborhood frameworks are more attractive over destinations where plant water utilization will have an antagonistic effect on the nearby water supply.
Fuel Supply Environment	Data is required on access and separation to: existing fuel transport frameworks, contending fuel transporters, and exchange fuel conveyance frameworks. On location space may be required for fuel stockpiling. By and large, destinations with access to contending fuel transporters and interchange fills are desirable over locales without this right to gain entrance.
Access to Grid	Any new transmission line needed to interface the force plant into the electrical transmission framework might be a huge expense of plant siting and a significant reason for group concern. By and large, shorter new power lines are liked to longer new lines, and more level-voltage lines are wanted to higher-voltage lines. Updating or modifying existing lines is now and then wanted to putting in new lines. Transmission associations that build framework unwavering quality and soundness and diminishing framework misfortunes are alluring.
Rights of Way	Permission by the owner of a piece of land to others to pass over his or her territory as a right to gain entrance easement. Open civilities, for example, roads and walkways (trails) are some piece of general society right of way. Property privileges of a manager of restrictive data that may be ensured under law. In getting, this term alludes to the information having a place with the builder, and may incorporate money related data, protected innovation (ideas, outlines, methods), specialized documentation, craftsmanship, and so forth.
Transportation Options Available	A new power plant will oblige transmission and dispersion progressions to join the plant to the electrical transmission framework. The potential for effects from those progressions is likewise of enthusiasm to neighborhood groups and contiguous landowners. Financial effects of transmission and appropriation progressions, for example, area utilize and right-of-way confinements, ought to be recognized. For the most part, more attractive destinations have fewer limitations and effects connected with obliged transmission and dispersion changes.

Labor and Skills Availability	A power plant obliges work for development and operation. Neighborhood groups can profit from these business good fortunes. For the most part, locales that can make utilization of nearby work are more attractive. These destinations might have a bigger gifted work drive inside a short separation from the plant site.
Cost and Economic Environment	**Delivered cost of energy** Sometimes, the expense of siting and developing a force plant is incorporated in the electric rates charged to clients. Assuming this is the case, the expense ought to be assessed to focus both the prompt and long haul-impacts on client rates and the impact on aggressiveness of business and industry. By and large, destinations that give an easier conveyed expense of electrical power are more desirable site. .**Future development limitations** The development of a plant at a specific site may make confinements on future advancement in the neighborhood its impact ashore utilize or through its utilization of nearby PSD air additions, water assets, of water release limit. By and large, destinations that force fewer confinements on future improvement may be more attractive. **Jobs and purchases** The investment effect of a plant incorporates the employments and buys connected with the development and operation of a plant. A cogeneration undertaking may additionally help to continue existing industry occupations in the group. By and large, locales that create or safeguard more occupations in the neighborhood be more attractive. [https://psc.wi.gov/]
CO2Transportation and Storage	For territories where all NAAQS regulations are met, the designer must think about the measures of "clean air" which could be utilized ("devoured"). This utilization of the current clean air is managed by the PSD regulations. The site assessment ought to incorporate the amount of the PSD addition is accessible and what amount of toxins could be emitted without utilizing up the accessible augmentation underneath NAAQS levels. The motivation behind force plant contamination regulations and emanations limits is to evade damage to open wellbeing and nature's turf. The worry is hoisted for adjacent populaces of elderly, wiped out, and extremely youngsters, who may have an expanded affectability to plant-related discharges. Adjacent offices, for example, healing centers, nursing homes, day forethought focuses, and evaluation schools may have populaces with expanded sensitivities. The "aggravation" effects of criminal dust are of specific concern to close-by occupants. There is open enthusiasm toward comprehension the sources, sorts, and levels of criminal clean that may be connected with a proposed plant, and the separation of dust sources from touchy areas, for example, adjacent living arrangements. By and large, more attractive destinations are those with fewer wellsprings of criminal dust and more excellent separations to adjoining habitations and touchy areas.

	[https://psc.wi.gov/]

These criteria are shown in Table 1. To express the criteria easier, the symbols in Table 1 were presented.

5. A fuzzy-TOPSIS approach

Fuzzy TOPSIS (Technique for Order Performance by similarity to Ideal solution) was initially created by (Hwang and Yoon, 1981); it is a standout amongst the most established techniques for tackling MCDM issue. It is centered around the assumption that the picked elective should have the longest partition from the negative perfect outcome, so the result that stretches the cost criteria and minimizes the benefits criteria and the briefest division from the positive flawless result, so the result that enlarges the benefit criteria and minimizes the expense criteria. In settled TOPSIS the weights and examinations of the criteria are known accurately. Nonetheless, (Hwang and Yoon, 1981) said that under a lot of people genuine circumstances crisp information are insufficient to model regular-circumstance since human judgments are dubious and can't be assessed with accurate numeric qualities. To expectation the equivocalness customarily developing in information from human judgments fuzzy set speculation has been melded in various MCDM procedures including TOPSIS. In fuzzy TOPSIS all the weights and evaluations are described by technique for semantic variables. Different fuzzy TOPSIS systems and procurements have been produced as of late. Chen and Hwang (1992) initially connected fuzzy numbers to create fuzzy TOPSIS. Triantaphyllou and Lin (1996) created a fuzzy TOPSIS technique in which relative closeness for every alternative is assessed focused around fuzzy number juggling operations. Liang (1999) recommended Fuzzy MCDM focused around ideal and anti-ideal ideas. Chen (2000) acknowledged triangular fuzzy numbers and characterized crisp Euclidean separation between two fuzzy numbers to stretch out the TOPSIS strategy to

fuzzy GDM circumstances. Chu (2002) and Chu and Lin (2002) again enhanced the technique proposed by Chen (2000). Chen and Tsao (2008) were to amplify the TOPSIS strategy focused around Interval-esteemed fuzzy sets in decision analysis. Jahanshahloo et al. (2006) and Chu and Lin (2009) augmented the fuzzy TOPSIS technique focused around alpha level sets with interim number-crunching. Chen and Lee (2010) enlarged fuzzy TOPSIS focused around sort-2 fuzzy TOPSIS system keeping in mind the end goal to give extra level of opportunity to speak to the vulnerabilities and fuzziness of this present reality. Fuzzy TOPSIS has been presented for different multi-trait choice-production issues. Yong (2006) utilized fuzzy TOPSIS for plant area determination and Chen et al. (2006) utilized fuzzy TOPSIS for supplier determination. Kahraman et al. (2007) used fuzzy TOPSIS for mechanical automated framework choice. Wang and Chang (2007) connected fuzzy TOPSIS to help the Air Force Academy in Taiwan pick ideal introductory preparing Criteria for site determination of TPP airplane in a fuzzy environment. Benitez et al. (2007) displayed a fuzzy TOPSIS approach for assessing alterably the administration nature of three inns of a vital organization in Gran Canaria Island by means of overviews. Kahraman et al. (2007) proposed a fuzzy progressive TOPSIS model for the multi-criteria assessment of the modern automated frameworks. Ashtiani et al. (2008) utilized interim-esteemed fuzzy TOPSIS strategy is pointing at taking care of MCDM issues in which the weights of criteria are unequal, utilizing interim esteemed fuzzy sets ideas. Ekmekcioglu et al. (2010) utilized an altered fuzzy TOPSIS to select civil strong waste transfer strategy and site. Kutlu and Ekmekcioglu (2011) utilized fuzzy TOPSIS coordinated with fuzzy AHP to propose another FMEA 'disappointment modes & impacts dissection's which conquers the deficiencies of conventional FMEA. Kaya and Kahraman (2011) proposed a changed fuzzy TOPSIS for choice

of the best vitality engineering elective. Kim et al. (2011) utilized fuzzy TOPSIS for displaying customer's item reception process.

Procedural Steps of Fuzzy-TOPSIS

TOPSIS technique was firstly proposed by (Hwang and Yoon, 1981). The essential idea of this technique is that the picked alternative (suitable alternative) ought to have the most limited separation from the positive ideal solution and the most remote separation from negative ideal solution. Positive ideal solution will be a result that augments the profit criteria and minimizes adverse criteria, although the negative ideal solution minimizes the profit criteria and amplifies the antagonistic criteria. The steps included in TOPSIS technique are as takes after:

Step 1: A panel of five experts (decision-makers) was formed, and then identifies the evaluation criteria.

Step 2: Every decision-maker states the importance level (weight) of each criterion using a linguistic variable.

Step 3: The ratings of various alternatives are found out in compliance with each criterion with the help of the linguistic rating variables.

Step 4**:** Construct a fuzzy multi-criteria group decision making (FMCGDM) matrix, which consist crisps values of criteria and alternatives. The crisps value C_v is calculated as,

$$C_v = \left(\frac{2a+7b+7c+2d}{18}\right)\left(\frac{7w}{18}\right) \tag{5}$$

Here, a, b, c, d are the generalized trapezoidal fuzzy elements (Rao and Shankar, 2012).

Step 5: Construct the normalized decision matrix. The normalized value r_j is calculated as,

$$r_j = \frac{f_j}{\sqrt{\sum_{j=1}^{n} f_j^2}} \tag{6}$$

Step 6: Construct weighted normalized decision matrix. The weighted normalized v_j is calculated as,

$$v_j = w \times r_j \tag{7}$$

Step 7: Determine positive ideal solution (maximum value on each criterion) and negative ideal solution (minimum value on each criterion) from the weighted normalized decision matrix. In the below equation F^1 is the set of benefit criteria and F^2 is the set of cost criteria.

$$V^{*+} = \begin{cases} \max\limits_{1 \le j \le n}(v_j) & (f_j \in F^1) \\ \min\limits_{1 \le j \le n}(v_j) & (f_j \in F^2) \end{cases} \tag{8}$$

$$V^{*-} = \begin{cases} \max\limits_{1 \le j \le n}(v_j) & (f_j \in F^1) \\ \min\limits_{1 \le j \le n}(v_j) & (f_j \in F^2) \end{cases} \tag{9}$$

Step 7: Calculate the Euclidean distance between positive ideal solution and negative ideal solution for each alternative.

$$D^{*+}(x_j) = \sqrt{\sum_{j=1}^{m}(v_j - V^{*+})^2} \tag{10}$$

$$D^{*-}(x_j) = \sqrt{\sum_{j=1}^{m}(v_j - V^{*-})^2} \tag{11}$$

Step 8: Calculate the closeness coefficient of each alternative.

$$C^*(x_j) = \frac{D^{*-}(x_j)}{D^{*+}(x_j) + D^{*-}(x_j)} \tag{12}$$

6. Empirical research

Selecting a proper site for TPP is very important for its long term efficiency and so many factors come into picture when deciding where to install the plant. We know that it may not be possible to get everything which is desirable at a single place but still the location must contain on optimum mix of the requirement for setting to be feasible for long term economic justification of plant. Therefore, the proposed model has been used to evaluate and select suitable site for TPP. A single-level performance appraisal hierarchy has been designed as shown in Table 1.

Table 1: Evaluation Index System of Power Plant Site Selection

Evaluation Index of Power Plant Site Selection, C	Land Availability or CCS Footprint, C_1
	Seismic Stability, C_2
	Floodplain, C_3
	Weather, C_4
	Existing Site Hazards, C_5
	Existing Land Use, C_6
	Restricted Air Space, C_7
	Cultural Resources, C_8
	Threatened and Endangered Species, C_9
	Proximity to Public Access Areas, C_{10}
	State/Local Environmental Requirements, C_{11}
	Proximity to Class I Visibility Areas, C_{12}
	Proximity to Tribal Lands, C_{13}
	Access to Cooling Water, C_{14}
	Fuel Supply Environment, C_{15}
	Access to Grid, C_{16}
	Rights of Way, C_{17}
	Transportation Options Available, C_{18}
	Labor and Skills Availability, C_{19}
	Cost and Economic Environment, C_{20}
	CO2Transportation and Storage, C_{21}

For assessing priority weight of evaluation indices, a panel of five chiefs-(Dms), has been shaped to express their subjective inclination in linguistic terms. Keeping in mind the end goal to give necessity weight against different criteria; the choice-production bunch has been trained to utilize the accompanying linguistic terms: Very Low (VL), Low (L), Medium (M), High (H), and Very High (VH). Correspondingly, decision-making group has additionally been educated to utilize the etymological scale to express their subjective judgment against execution rating of every assessment lists of alternatives. The accompanying linguistic scale has been used to allocate execution appropriateness rating against records: Very Poor (VP), Poor (P), Satisfactory (S), Impressive, (I) and Extremely Impressive (EI). The five-member linguistic terms and their corresponding fuzzy numbers are shown in Table 2.

Table 2: Five-member linguistic terms and their corresponding fuzzy numbers

Linguistic terms for weight assignment	Linguistic terms for ratings	Generalized trapezoidal fuzzy numbers
Very Low, VL	Very Poor, VP	(0, 0, 0.125, 0.25)
Low, L	Poor, P	(0.125, 0.25, 0.375, 0.5)
Medium, M	Satisfactory, S	(0.375, 0.5, 0.5, 0.625)
High, H	Impressive, I	(0.5, 0.625, 0.75, 0.875)
Very High, VH	Extremely Impressive, EI	(0.75, 0.875, 1, 1)

After the linguistic variables for evaluating the performance ratings and priority weight of distinctive assessment indices has been acknowledged by the leaders-(DDs), the decision-makers have been asked to utilize aforementioned linguistic scales to evaluate performance rating against each of the alternatives criteria shown in Tables 4-7. Similarly, subjective priority weight evaluation index has been assessed by the DMs and that sown in Table 3.

Table 3: Fuzzy priority weight (in linguistic scale) of indices assigned by DMs

Performance metrics	Priority weights in linguistic term				
	DM1	DM2	DM3	DM4	DM5
C_1	VH	VH	VH	H	H
C_2	H	H	H	M	M
C_3	M	H	H	H	H
C_4	M	M	M	M	L
C_5	M	M	M	L	M
C_6	M	M	M	L	L
C_7	M	M	L	L	L
C_8	L	L	M	M	L
C_9	H	H	M	M	M
C_{10}	M	H	H	H	H
C_{11}	M	M	L	L	M
C_{12}	L	M	M	M	M
C_{13}	M	M	L	M	M
C_{14}	M	M	H	H	H
C_{15}	VH	VH	VH	VH	VH
C_{16}	VH	VH	VH	VH	VH
C_{17}	M	H	H	H	H
C_{18}	H	H	H	VH	VH
C_{19}	H	H	VH	VH	VH
C_{20}	VH	VH	H	H	VH
C_{21}	VH	VH	VH	VH	H

Table 4: Appropriateness rating (in linguistic scale) of indices assigned by DMs **(Alternative 1)**

Performance metrics	Ratings in linguistic term (A_1)				
	DM1	DM2	DM3	DM4	DM5
C_1	S	S	I	I	I
C_2	I	I	I	S	S
C_3	S	S	P	P	P
C_4	S	P	P	P	S
C_5	S	S	S	S	S
C_6	I	I	I	I	I
C_7	P	P	S	S	S
C_8	S	S	S	P	P
C_9	S	P	P	S	S
C_{10}	S	S	I	I	I
C_{11}	S	I	I	S	S
C_{12}	I	I	I	S	S
C_{13}	S	I	I	I	I
C_{14}	I	I	I	I	S
C_{15}	I	I	I	EI	EI
C_{16}	EI	EI	I	I	I

C_{17}	EI	I	I	I	EI
C_{18}	EI	EI	I	I	EI
C_{19}	I	I	EI	EI	EI
C_{20}	I	EI	EI	EI	I
C_{21}	I	I	I	EI	EI

Table 5: Appropriateness rating (in linguistic scale) of indices assigned by DMs **(Alternative 2)**

Performance metrics	Ratings in linguistic term (A_2)				
	DM1	DM2	DM3	DM4	DM5
C_1	I	I	I	I	EI
C_2	I	EI	I	I	I
C_3	S	S	P	P	P
C_4	S	P	P	P	S
C_5	S	S	S	S	S
C_6	I	I	I	I	I
C_7	P	P	S	S	S
C_8	S	S	S	P	P
C_9	S	P	P	S	S
C_{10}	I	I	I	I	S
C_{11}	S	I	I	I	I
C_{12}	S	S	I	I	I
C_{13}	S	I	I	I	S
C_{14}	I	I	I	S	S
C_{15}	EI	EI	I	I	I
C_{16}	EI	EI	EI	I	I
C_{17}	EI	EI	I	EI	I
C_{18}	I	I	EI	EI	EI
C_{19}	I	EI	EI	EI	EI
C_{20}	EI	EI	EI	EI	I
C_{21}	I	I	I	EI	EI

Table 6: Appropriateness rating (in linguistic scale) of indices assigned by DMs **(Alternative 3)**

Performance metrics	Ratings in linguistic term (A_3)				
	DM1	DM2	DM3	DM4	DM5
C_1	S	S	S	S	I
C_2	S	I	I	S	S
C_3	P	P	VP	VP	P
C_4	P	P	P	P	VP

C_5	VP	VP	P	P	P
C_6	S	S	I	S	S
C_7	P	P	P	P	S
C_8	S	S	P	P	P
C_9	P	P	VP	P	P
C_{10}	P	S	S	S	P
C_{11}	P	S	S	S	S
C_{12}	S	S	S	P	P
C_{13}	P	P	P	S	S
C_{14}	S	S	S	S	I
C_{15}	S	S	S	I	I
C_{16}	S	S	I	I	I
C_{17}	I	I	I	I	S
C_{18}	I	I	I	S	S
C_{19}	I	S	I	S	I
C_{20}	I	I	S	I	I
C_{21}	S	S	I	I	I

Table 7: Appropriateness rating (in linguistic scale) of indices assigned by DMs **(Alternative 4)**

Performance metrics	Ratings in linguistic term (A_4)				
	DM1	DM2	DM3	DM4	DM5
C_1	S	I	I	I	I
C_2	I	I	S	S	S
C_3	P	P	VP	VP	P
C_4	P	P	P	P	VP
C_5	VP	VP	P	P	P
C_6	I	I	I	S	S
C_7	P	P	P	P	S
C_8	S	S	P	P	P
C_9	P	P	VP	P	P
C_{10}	I	I	S	S	S
C_{11}	I	S	S	I	I
C_{12}	I	I	S	S	I
C_{13}	I	I	S	S	S
C_{14}	I	I	I	I	S
C_{15}	S	I	I	I	I
C_{16}	S	S	I	I	I
C_{17}	I	I	I	I	EI
C_{18}	I	I	EI	I	I
C_{19}	EI	I	I	I	EI
C_{20}	EI	EI	I	I	EI
C_{21}	EI	I	I	I	EI

Utilizing the idea of Generalized Trapezoidal Fuzzy Numbers (GTFNs) in fuzzy set hypothesis, the judgemental hypothesis is converted to Trapezoidal Fuzzy Numbers. After that, the aggregated decision-making cum assessment table is constructed. The aggregated fuzzy appropriateness rating against an individual index with corresponding importance weight is analysed.

By using the fuzzy operational rules (Eqs. 1-4), estimating the aggregated weight as well as aggregated rating (combined choice of the decision-makers) for all the considered criterion and then convert linguistic term assigned (indices) by DMs to fuzzy number strictly follow the Five-member linguistic terms and their corresponding fuzzy numbers. So the aggregated fuzzy priority weight and aggregated fuzzy rating of indices calculated values are shown in Table 8 and Table 9, respectively**.**

Table 8: Aggregated Priority weight (Level) and calculated crisps value

Level	Aggregated fuzzy weight, w_i	Crisps Value(C_V)
C_1	[0.650, 0.775, 0.900, 0.950]	0.322
C_2	[0.450, 0.575, 0.650, 0.775]	0.238
C_3	[0.475, 0.600, 0.700, 0.825]	0.253
C_4	[0.325, 0.450, 0.475, 0.600]	0.180
C_5	[0.325, 0.450, 0.475, 0.600]	0.180
C_6	[0.275, 0.400, 0.450, 0.575]	0.165
C_7	[0.225, 0.350, 0.425, 0.550]	0.151
C_8	[0.225, 0.350, 0.425, 0.550]	0.151
C_9	[0.450, 0.575, 0.650, 0.775]	0.238
C_{10}	[0.475, 0.600, 0.700, 0.825]	0.253
C_{11}	[0.275, 0.400, 0.450, 0.575]	0.165
C_{12}	[0.325, 0.450, 0.475, 0.600]	0.180
C_{13}	[0.325, 0.450, 0.475, 0.600]	0.180
C_{14}	[0.450, 0.575, 0.650, 0.775]	0.238
C_{15}	[0.750, 0.875, 1.000, 1.000]	0.359
C_{16}	[0.750, 0.875, 1.000, 1.000]	0.359
C_{17}	[0.475, 0.600, 0.700, 0.825]	0.253
C_{18}	[0.600, 0.875, 0.850, 0.925]	0.327
C_{19}	[0.600, 0.875, 0.850, 0.925]	0.327
C_{20}	[0.600, 0.875, 0.850, 0.925]	0.327
C_{21}	[0.700, 0.825, 0.950, 0.975]	0.341

Table 9: Aggregated Appropriateness rating (Level) (Alternative1-4)

Level	Alternative-1	Alternative-2	Alternative-3	Alternative-4
C_1	[0.45, 0.58, 0.65, 0.78]	[0.55, 0.68, 0.80, 0.90]	[0.40, 0.53, 0.55, 0.68]	[0.48, 0.60, 0.70, 0.83]
C_2	[0.45, 0.58, 0.65, 0.78]	[0.55, 0.68, 0.80, 0.90]	[0.45, 0.58, 0.65, 0.78]	[0.45, 0.58, 0.65, 0.78]
C_3	[0.23, 0.35, 0.43, 0.55]	[0.23, 0.35, 0.43, 0.55]	[0.08, 0.15, 0.28, 0.40]	[0.08, 0.15, 0.28, 0.40]
C_4	[0.23, 0.35, 0.43, 0.55]	[0.23, 0.35, 0.43, 0.55]	[0.10, 0.20, 0.33, 0.45]	[0.10, 0.20, 0.33, 0.45]
C_5	[0.38, 0.50, 0.50, 0.63]	[0.38, 0.50, 0.50, 0.63]	[0.08, 0.15, 0.28, 0.40]	[0.08, 0.15, 0.28, 0.40]
C_6	[0.50, 0.63, 0.75, 0.88]	[0.50, 0.63, 0.75, 0.88]	[0.40, 0.53, 0.55, 0.68]	[0.45, 0.58, 0.65, 0.78]
C_7	[0.28, 0.40, 0.45, 0.58]	[0.28, 0.40, 0.45, 0.58]	[0.18, 0.30, 0.40, 0.53]	[0.18, 0.30, 0.40, 0.53]
C_8	[0.28, 0.40, 0.45, 0.58]	[0.28, 0.40, 0.45, 0.58]	[0.23, 0.35, 0.43, 0.55]	[0.23, 0.35, 0.43, 0.55]
C_9	[0.28, 0.40, 0.45, 0.58]	[0.28, 0.40, 0.45, 0.58]	[0.10, 0.20, 0.33, 0.45]	[0.10, 0.20, 0.33, 0.45]
C_{10}	[0.45, 0.58, 0.65, 0.78]	[0.48, 0.60, 0.70, 0.83]	[0.28, 0.40, 0.45, 0.58]	[0.43, 0.45, 0.60, 0.73]
C_{11}	[0.45, 0.58, 0.65, 0.78]	[0.48, 0.60, 0.70, 0.83]	[0.33, 0.45, 0.48, 0.60]	[0.45, 0.58, 0.65, 0.78]
C_{12}	[0.45, 0.58, 0.65, 0.78]	[0.45, 0.58, 0.65, 0.78]	[0.28, 0.40, 0.45, 0.58]	[0.45, 0.58, 0.65, 0.78]
C_{13}	[0.48, 0.60, 0.70, 0.83]	[0.45, 0.58, 0.65, 0.78]	[0.23, 0.35, 0.43, 0.55]	[0.43, 0.45, 0.60, 0.73]
C_{14}	[0.48, 0.60, 0.70, 0.83]	[0.45, 0.58, 0.65, 0.78]	[0.40, 0.53, 0.55, 0.68]	[0.48, 0.60, 0.70, 0.83]
C_{15}	[0.60, 0.88, 0.85, 0.93]	[0.60, 0.88, 0.85, 0.93]	[0.43, 0.55, 0.60, 0.73]	[0.48, 0.60, 0.70, 0.83]
C_{16}	[0.60, 0.88, 0.85, 0.93]	[0.65, 0.77, 0.90, 0.95]	[0.45, 0.58, 0.65, 0.78]	[0.45, 0.58, 0.65, 0.78]
C_{17}	[0.60, 0.88, 0.85, 0.93]	[0.65, 0.77, 0.90, 0.95]	[0.48, 0.60, 0.70, 0.83]	[0.55, 0.68, 0.80, 0.90]
C_{18}	[0.65, 0.77, 0.90, 0.95]	[0.65, 0.77, 0.90, 0.95]	[0.45, 0.58, 0.65, 0.78]	[0.55, 0.68, 0.80, 0.90]
C_{19}	[0.65, 0.77, 0.90, 0.95]	[0.70, 0.83, 0.95, 0.98]	[0.45, 0.58, 0.65, 0.78]	[0.60, 0.88, 0.85, 0.93]
C_{20}	[0.65, 0.77, 0.90, 0.95]	[0.70, 0.83, 0.95, 0.98]	[0.48, 0.60, 0.70, 0.83]	[0.60, 0.88, 0.85, 0.93]
C_{21}	[0.60, 0.88, 0.85, 0.93]	[0.60, 0.88, 0.85, 0.93]	[0.45, 0.58, 0.65, 0.78]	[0.60, 0.88, 0.85, 0.93]

After estimated aggregated fuzzy priority weight and aggregated fuzzy rating of indices, then we proceeded after converting the indices in to crisp value of estimated aggregated fuzzy priority weight and aggregated fuzzy rating by using Eq. (5) and the vales are shown in Table 8 (crisps weight value)and Table 9 (crisps rating value). Then we constructed a fuzzy multi-criteria group decision making (FMCGDM) matrix (Table 10).

Then we normalized the fuzzy multi-criteria group decision making (FMCGDM) matrix by help of Eq. (6) and the normalized decision matrix shown in Table 11. After constructed the normalization decision matrix, we proceed to calculate weighted normalized decision Matrix by using Eq. (7) and shown in Table 12. Then we calculated the fuzzy positive ideal solution (FPIS)

and the fuzzy negative ideal solution (FNIS) by using Eq. (8- 9) and the values are shown in Table 13.

According to the concept of TOPSIS, we calculated the fuzzy positive ideal solution (FPIS) and the fuzzy negative ideal solution (FNIS). And, then, we can calculate the Euclidean distance of each alternative from FPIS and FNIS, respectively. Finally, a closeness coefficient of each alternative is calculated by using the (Eq. 10-12) to determine the ranking order of all alternatives. The higher value of closeness coefficient (**0.5654, 0.5784, 0.4334 and 0.4973**) indicates that an alternative is closer to FPIS and farther from FNIS simultaneously. According to the closeness coefficient (C*), the ranking of each alternative are shown in Table 14. Fig. 3 shows the closeness coefficient (C*) with respect to alternatives.

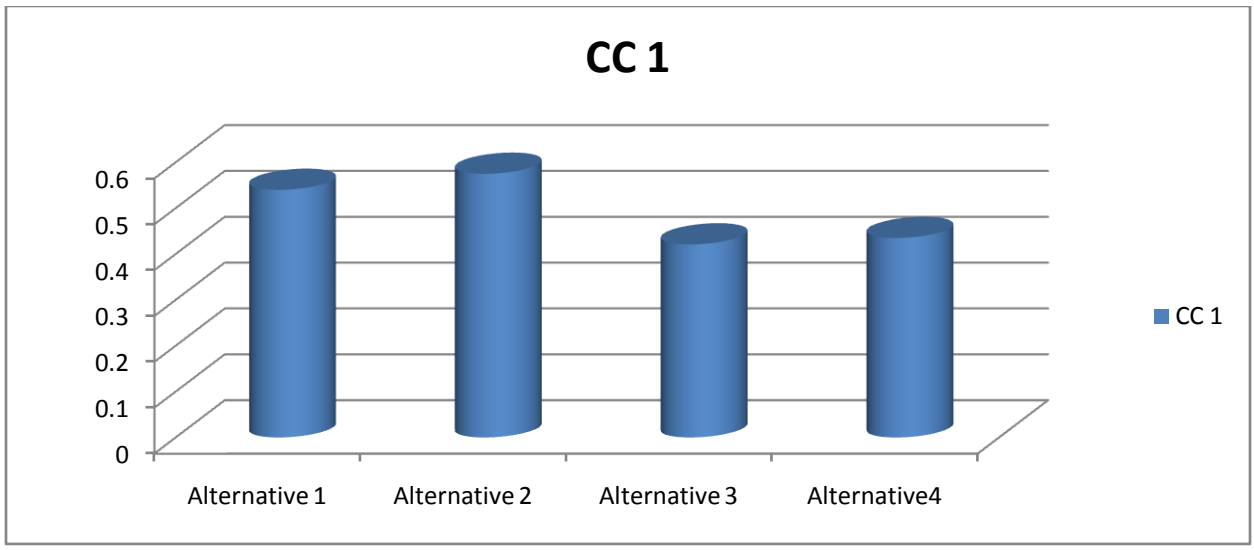


Fig. 3: Relation between closeness coefficient (C*) and alternatives

Table 10: A fuzzy multi-criteria group decision making (FMCGDM) matrix

Alternatives	Criteria																				
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}	C_{21}
A_1	0.24	0.24	0.15	0.15	0.19	0.27	0.17	0.17	0.17	0.24	0.24	0.24	0.25	0.25	0.33	0.33	0.33	0.32	0.32	0.32	0.33
A_2	0.29	0.29	0.15	0.15	0.19	0.27	0.17	0.17	0.17	0.25	0.25	0.24	0.24	0.24	0.33	0.32	0.32	0.32	0.34	0.34	0.33
A_3	0.21	0.24	0.09	0.10	0.09	0.21	0.14	0.15	0.10	0.17	0.18	0.17	0.15	0.21	0.22	0.24	0.25	0.24	0.24	0.25	0.24
A_4	0.25	0.24	0.09	0.10	0.09	0.24	0.14	0.15	0.10	0.22	0.24	0.24	0.22	0.25	0.25	0.24	0.29	0.29	0.24	0.24	0.24

Table 11: Normalized Decision Matrix

Alternatives	Criteria																				
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}	C_{21}
A_1	0.48	0.47	0.61	0.59	0.64	0.54	0.55	0.53	0.60	0.54	0.52	0.53	0.57	0.53	0.58	0.58	0.55	0.54	0.55	0.55	0.57
A_2	0.58	0.57	0.61	0.59	0.64	0.54	0.55	0.53	0.60	0.56	0.55	0.53	0.55	0.50	0.58	0.56	0.53	0.54	0.59	0.58	0.57
A_3	0.42	0.47	0.36	0.39	0.30	0.42	0.45	0.47	0.37	0.38	0.39	0.38	0.34	0.44	0.38	0.42	0.42	0.41	0.42	0.43	0.42
A_4	0.51	0.47	0.36	0.39	0.30	0.58	0.45	0.47	0.37	0.50	0.52	0.53	0.50	0.53	0.44	0.42	0.48	0.49	0.42	0.41	0.42

Table 12: Weighted Normalized Decision Matrix

Alternatives	Criteria																				
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}	C_{21}
A_1	0.16	0.11	0.15	0.11	0.12	0.09	0.08	0.08	0.15	0.14	0.09	0.10	0.10	0.12	0.20	0.21	0.14	0.18	0.18	0.18	0.20
A_2	0.19	0.14	0.15	0.11	0.12	0.09	0.08	0.08	0.15	0.14	0.09	0.10	0.10	0.12	0.20	0.20	0.14	0.18	0.19	0.19	0.20
A_3	0.14	0.11	0.09	0.07	0.05	0.07	0.07	0.07	0.09	0.10	0.06	0.07	0.06	0.10	0.14	0.15	0.11	0.13	0.14	0.14	0.14
A_4	0.16	0.11	0.09	0.07	0.05	0.08	0.07	0.07	0.09	0.13	0.09	0.10	0.09	0.12	0.16	0.15	0.12	0.16	0.14	0.13	0.14

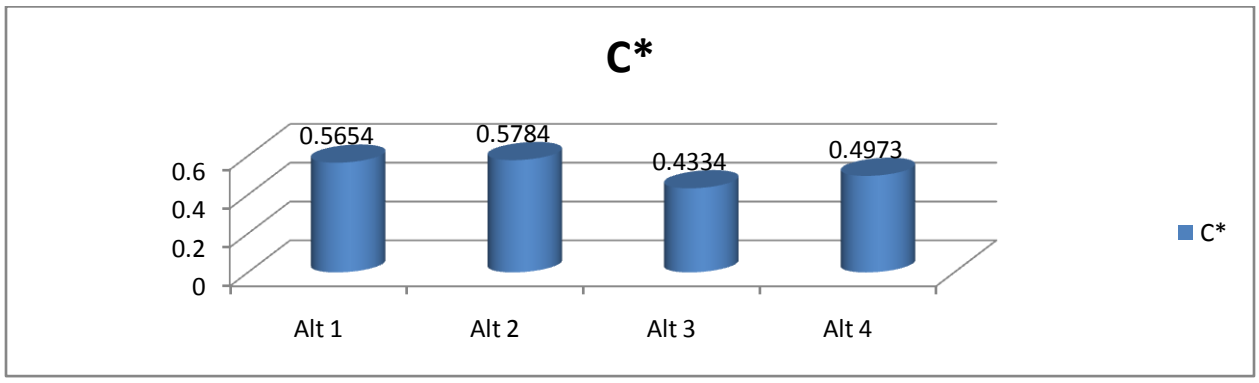
Table 13: Positive and Negative Ideal Solution

Ideal Sol'n	Criteria																				
	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}	C_{14}	C_{15}	C_{16}	C_{17}	C_{18}	C_{19}	C_{20}	C_{21}
V_1^{*+}	0.19	0.14	0.09	0.11	0.05	0.07	0.08	0.08	0.09	0.14	0.09	0.07	0.06	0.12	0.20	0.21	0.14	0.18	0.18	0.13	0.20
V_2^{*-}	0.14	0.11	0.15	0.07	0.12	0.09	0.07	0.07	0.15	0.10	0.06	0.10	0.10	0.10	0.14	0.15	0.11	0.13	0.14	0.19	0.14

Table 14: The Distance of alternative to positive/negative ideal solution, the related closeness coefficient and ranking

Serial number	Alternatives	Distance D^{*+}	Distance D^{*-}	Closeness coefficients(C*)	Ranking
i	A_1	0.1389	0.1807	0.5654	2
ii	**A_2**	**0.1371**	**0.1881**	**0.5784**	**1**
iii	A_3	0.1549	0.1185	0.4334	4
iv	A_4	0.1296	0.1282	0.4973	3

According to the Closeness coefficients (C*), we clearly understood the assessment status of each alternative and also identified the ranking order (**A_2> A_1> A_3> A_4**) of all alternatives. So based on these ranking criteria we can easily choose the best alternative (**A_2**).



7. Conclusion

The major outcomes of this proposed work have been highlighted as follows:

- A TOPSIS approach combined with fuzzy logic for site selection of TPP is presented.
- This method is simple and can transform complex decision making problem into clear and simple one.
- Throughout the evaluation process, this method not only eliminates the influence of subjective factors, but also makes the outcomes of the evaluation to be more objective.

- ❖ Generally site selection of TPP is governed by large organizations only but the above concept is very useful for academic point of view. .

So this method has certain reference value to the site of TPP in real life. This work proposes an incorporated approach in a precise manner with a plan to select the best alternative in spite of clashing criteria. Hence, the commitment of this paper is to propose an effective and efficient choice skeleton for assessment and ranking of alternative site selection of TPPs.

8. List of References

Ashrafzadeh, M., Rafiei, F. M., Isfahani, N. M., Zare, Z. (2012), Application of fuzzy TOPSIS method for the selection of Warehouse Location: A Case Study, Interdisciplinary Journal of Contemporary Research in Business;Jan2012, Vol. 3 Issue 9, pp 655.

Ashtiani, B., Haghighirad, F., Makui, A. and Montazer, G. A. (2008), Extension of fuzzy TOPSIS method based on interval-valued fuzzy sets, Applied Soft Computing, Vol. 9, No. 2, pp. 457-461.

Benitez, J. M., Martin, J. C. and Roman, C. (2007), Using fuzzy number for measuring quality of service in the hotel industry, Tourism Management, Vol. 28, No. 2, pp. 544-555.

Brown, P. A. and Gibson, D. F. (1972), A quantified model for facility site selection: An application to a multi-facility location problem, AIIE Transactions, Vol. 4, pp. 1–10.

Chen, C. T. (2000), Extension of the TOPSIS for group decision-making under fuzzy environment, Fuzzy Sets and Systems, Vol. 114, No. 1, pp. 1-9.

Chen, C. T., Lin, C. T. and Huang, S. F. (2006), A fuzzy approach for supplier evaluation and selection in supply chain management, International Journal of Production Economics, Vol. 102, No. 2, pp. 289-301.

Chen, C.T. (2001), A fuzzy approach to select the location of the distribution center, Fuzzy Sets and Systems, Vol. 118, pp 65–73.

Chen, S. J. and Hwang, C. L. (1992), Fuzzy multi attribute decision making, lecture notes in economics and mathematical system series, Vol. 375. Springer-Verlag, New York.

Chen, S.M. and Lee, L.W. (2010), Fuzzy multiple attributes group decision-making based on the interval type-2 TOPSIS method, Expert Systems with Applications, Vol. 37, No. 4, pp. 2790-2798.

Chen, T.Y. and Tsao, C.Y. (2008), The interval-valued fuzzy TOPSIS method and experimental analysis, Fuzzy Sets and Systems, Vol. 159, No. 11, pp. 1410-1428.

Chou, S.Y., Chang, Y.H. and Shen, C.Y. (2008), A fuzzy simple additive weighting system under group decision-making for facility location selection with objective/subjective attributes, European Journal of Operational Research, Vol. 189, pp 132–145.

Chu, T. (2002), Selecting plant location via a fuzzy TOPSIS approach, International Journal of Advanced Manufacturing Technology, Vol. 20, No. 11, pp. 859-864.

Chu, T. and Lin, Y. C. (2002), Improved extensions of the TOPSIS for group decision making under fuzzy environment, Journal of Information and Optimization Sciences, Vol. 23, pp. 273-286.

Chu, T. C. and Lin, Y. C. (2009), An interval arithmetic based fuzzy TOPSIS model, Expert Systems with Applications, Vol. 36, No. 8, pp. 10870-10876.

Ekmekcioglu, M., Kaya, T. and Kahraman, C. (2010), Fuzzy multi-criteria disposal method and site selection for municipal solid waste, Waste Management, Vol. 30, No. 8-9, pp. 1729-1736.

Ghose, S. (2008), West Coast Regional Carbon Sequestration Partnership Annual Business Meeting, Anchorage AK, slide. 1-18.

Hwang C. L. and Yoon K. (1981), Multiple Attribute Decision Making Methods and Applications, A State-of-the-Art Survey, Springer Verlag, New York.

Jahanshahloo, G. R. Hosseinzadeh Lotfi, F. and Izadikhah, M. (2006), Extension of the TOPSIS method for decision-making problems with fuzzy data, Applied Mathematics and Computation, Vol. 181, No. 2, pp. 1544–1551.

Kahraman, C., Cevik, S., Ates, N. Y. and Gulbay, M. (2007), Fuzzy multi-criteria evaluation of industrial robotic systems, Computers & Industrial Engineering, Vol. 52, No. 4, pp. 414-433.

Kahraman, C., Ruan, D. and Dogan, I. (2003), Fuzzy group decision-making for facility location selection, Information Sciences, Vol. 157, pp. 135–153.

Kannan G., Shaligram P., P. Sasi Kumar (2009), A hybrid approach using ISM and fuzzy TOPSIS for the selection of reverse logistics provider , Resour. Conserv. Recycl, 54, pp. 28–36.

Kaya, T. and Kahraman, C. (2011), Multi-criteria decision making in energy planning using a modified fuzzy TOPSIS methodology, Expert Systems with Applications, Vol. 38, No. 6, pp. 6577-6585

Kim, S., Lee, K., Cho, J. K. and Kim, C.O. (2011), Agent-based diffusion model for an automobile market with fuzzy TOPSIS-based product adoption process, Expert Systems with Applications, Vol. 38, No. 6, pp. 7270-7276.

Kuo, R.J., Chi, S.C. and Kao, S.S. (1999), A decision support system for locating convenience store through fuzzy AHP, Computers and Industrial Engineering, Vol. 37, pp 323–326.

Kuo, R.J., Chi, S.C. and Kao, S.S. (2002), A decision support system for selecting convenience store location through integration of fuzzy AHP and artificial neural network, Computers in Industry, Vol. 47, pp 199–214.

Kutlu, A. C. and Ekmekcioglu, M. (2011), Fuzzy failure modes and effects analysis by using fuzzy TOPSIS integrated with fuzzy AHP, Expert Systems with Applications, Vol. 39, No. 1, Article in Press.

Liang, G. S. (1999), Fuzzy MCDM based on ideal and anti-ideal concepts, European Journal of Operational Research, Vol. 112, No. 3, pp. 682-691.

Liang, G.S. and Wang, M.J.J. (1991), A fuzzy multi-criteria decision-making method for facility site selection, International Journal of Production Research, Vol. 29, pp. 2313–2330.

Rao, P.P.B. and Ravi Shankar, N. (2012), Ranking Generalized Fuzzy Numbers using Area, Mode, Spreads and Weights, International Journal of Applied Science and Engineering, Vol. 10, No.1, pp. 41-57.

Tavakkoli-Moghaddam, R. and Mousavi, S.M. (2011), An integrated AHP-VIKOR methodology for plant location selection, IJE Transactions B: Applications, Vol. 24, No. 2, pp. 127-137

Triantaphyllou, E. and Lin, C.L. (1996), Development and evaluation of five fuzzy multi attribute decision making methods, International Journal of Approximate Reasoning, Vol. 14, No. 4, pp. 281–310.

Wang, T. C. and Chang, T. H. (2007), Application of TOPSIS in evaluating initial training aircraft under a fuzzy environment, Expert Systems with Applications, Vol. 33, No. 4, pp. 870-880.

Yong, D. (2006), Plant location selection based on fuzzy TOPSIS, International Journal of Advanced Manufacturing Technologies, Vol. 28, No. 7-8, pp. 323-326.

Zangeneh, A., Jadid, S. and Rahimi-Kian, A. (2011), A fuzzy environmental-technical economic model for distributed generation planning, Energy, Vol.36, No.2, pp.3437-3445.