KWAME NKRUMAH UNIVERSITY OF SCIENCE AND

TECHNOLOGY, KUMASI

LOCATION OF WATER TREATMENT PLANT USING THE AHP,PROMETHEE AND TOPSIS METHODOLOGY IN THE GYEME RIVER AT OBUASI

By

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Declaration

I hereby declare that this submission is my own work towards the award of the M.SC

degree and that, to the best of my knowledge, it contains no

material previously published by another person nor material which had been accepted for the award of any other degree of the university, except where due acknowledgement had been made in the text.

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Dedication

I dedicate this work to God almighty who granted me the strength to do this work. Secondly to my wife ,Mrs Charity Amissah-Edmund and daughter Awura Aba Ayensua Amissah-Edmund.All I want to say is that God richly bless them and help them to ful ll their dreams and aspiration in life. I also wish to state that, another dedication goes to all who nds this work as really important material which serves as the source of knowledge base to the research world.I also wish dedicate this work to my mum Mrs. Philomena Sackey who has cared for me though out my education.Not for getting Mr. Sackey My Dad,I say Ayekoo,

Congratulation to them all,May they see light at the end of the Tunnel.

Abstract

Facility location is a very important issue in our daily life and activities. In view of this, it is very important to look at the factors that in uence the location of a facility. In this case we want to lay emphasis on the location of water treatment plant in obuasi, purposely to serve the people in obuasi and the surrounding towns. The methods that the researcher employed is the AHP/PROMETHEE and TOPSIS methodology. After several models were reviewed,a data was collected and analyzed and it result interpreted. The ndings of the researcher was also stated together with the recommendation. Some of the factors that the researcher considered were; road network, nearness to the market, nearness to a source of power, nearness to a river source among others. The analysis was done with excel and the procedure was done by the pairwise comparison

matrix. The criteria and alternatives were carefully selected. However, the data which the researcher collected was through the use of questionnaire, prepared and administered to about 130 people who fall between the ages of 18 to 60 years. Various people whose work deal directly or indirectly with water, such as ltered water producers in and around Obuasi responded to the interview and answered the questionnaire given them. The management of the Ghana water Company and the Ghana statistical service were spoken to and their views taken. The di erence in the outranking ows together with the partial and complete ranking of alternatives gave rise to the Alternative Gausu a suburb of Obuasi being selected as the best location,which was con rmed by the TOPSIS methodology.

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The best reward you can give to those who have helped you,is to thank them.That is the more reason why I cannot fail to thank the following individuals.Firstly, I wish to acknowledge Dr. Richard Kena Boadi and Mr.Kwaku Fokuo Darkwa who in divers ways o ered academic advise, criticism and technical knowhow on the topic that I selected, to help me facilitate this work. In addition Dr. AKoraPrah who o ered his constructive criticism and creating an enabling environment for me to nish this project. My second thanks goes to my wife, Mrs Charity Amissah-Edmund who o ered her un inching support in various ways, in her bid to help me complete this work on schedule. The ultimate thanks goes to Mr. Charles Benning, who gave me the moral support to nish this work. To the manager of Ghana water company of the Obuasi branch as well as Mr. Richard Boakye the chief statistician of Obuasi Statistical service who gave me the needed data and information relating to the work. All I want to say is, I thank them all and God richly bless them in all their endeavors.

Contents

List of Abbreviation

AHP .... Analytic hierachicalProcess PROMETHEE .. Preferenceorgarnizationa method for enrichment evaluation

TOPSIS .... Technique for order Preference by similarity in ideal solutions MCDM .... Multi-Criteria Decision-Making

WPM ....Weighted Product Method

SAW .... Simple Additive Weighting , GTMA .... Graph Theory and Matrix Approach

GRA .... Grey Relational Analysis

DEA ....Data Envelopment Analysis ELECTRE .... Elimination and Et Choice Translating Reality

GAIA ....Geometric Analysis Iteractive aid

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Chapter 1

Introduction

1.1 Background of the study

Water as de ned by the Macmillan English Dictionary for Advance learner of the International student edition(2002) is the clear liquid that falls as rain and is used for things such as drinking and washing. Also the same Dictionary de nes treatment as the process of providing medical care in addition the term plant is subsequently de ned as the large machines and equipment used in industry. In view of the aforementioned, the researcher intended to do everything possible to help communities who are in need of quality drinking water, of which Obuasi and it catchment area are not an exception.

The need for water in our society for our daily use is undeniably a great concern for many stakeholders. In view of that, it is very important that we look at the issue holistically. According to the statistical service of Ghana at the Obuasi municipal branch, it was revealed in their report of the statistical service of Ghana (2010) census conducted that very little of the entire population of the Obuasi had access to quality good drinking water. In addition, other research work done by the same institution coupled with informal interviews conducted at the municipal revealed similar outcomes. Nevertheless, several e orts have been made to put things in it right perspective of which the steps taking include this research work.

AHP/PROMETHEE II method are used simultaneously to solve a real time facility location selection problem(Rao(2009)), it is seen that this method proves its applicability and potentiality to solve such type of decision-making problems with multiple con icting criteria and alternatives.

The selection of the most suitable facility location has become one of the most important and challenging issues in today‘s highly competitive business and manufacturing environment (Tompkins and White, 1984). The decision maker has to consider the facility location problems while expanding the existing production capacity, setting of a new production line or setting up of a new facility. The best location is to be selected, keeping in mind various

criteria/attributes a ecting the location selection decision-making problem and also the requirements of the organization. Hence, selecting the most appropriate facility location design from a nite set of possible alternatives for a given industrial application is really a di cult task. Usually, the problem of selecting a location, aims at minimizing the total transportation cost between di erent facilities so that the necessary materials and services can move uninterrupted within the entire organization. It will be a major setback for the organization, if the problems, such as backtracking, congestion, disturbed ow pattern and others, start functioning within the organization due to poor and unplanned location. Thus, the facility location selection decision becomes a strategic issue for an organization and has signi cant impact on its overall e ectiveness and performance. There are several quantitative and qualitative criteria, like material handling distance, adjacency score, shape ratio, exibility, accessibility, maintenance and others, which directly a ect the facility location selection decision. Among these criteria, some are bene cial in nature which are to be maximized, whereas, others are non-bene cial whose minimum values are always

preferable.

The process of choosing the most suitable facility location from a list of nite options give rise to a situation termed as a Multi-Criteria Decision-Making (MCDM) problem, requiring the ful llment of all the con icting criteria. There are quite a number of MCDM methods, like, Weighted Product Method (WPM), Simple Additive Weighting (SAW), Graph Theory and Matrix Approach (GTMA), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Grey Relational Analysis (GRA), Data Envelopment Analysis (DEA), Elimination and Et Choice Translating Reality (ELECTRE) and many more., are already available to give an e ective framework for evaluating the alternatives and selecting the best one. Other combinatorial optimization techniques, such as Simulated Annealing (SA), Generic Algorithm (GA), Ant Colony Optimization (ACO), Tabu search and many more, are also successfully used to unravel di culty associated with the location selection problems. Suitable computer packages and expert systems are also developed to overcome the di culty associated with the location problems and graphically generate the best location.

1.2 Statement of the Purpose

This research work is intended to ascertain the need for the location of the water treatment plant in Obuasi near the Gyeme River to help the inhabitant, especially for domestic use by most a ected people. The cry for water in some of the communities in Obuasi still remains the fulcrum of the problems the people are faced with. In view of the fact established above, something has to be done in order to locate a water treatment plant near the Gyeme River to serve the people in Obuasi and its environs. The information present currently has it that, the closest treatment plant serving people in Obuasi and nearby towns is at the Oda River in the Ashanti Region of Ghana. However looking at the number of people currently present at Obuasi which is nearly over 205,000, there is the need to locate the water treatment plant in Obuasi to salvage the situation. Most commercial activity depends largely on the use of water. In this regard, the location of this facility would be done using the Analytical Hierarchical process (AHP) and the Preference ranking organizational method for enrichment evaluation (PROMEHEE). Again, the TOPSIS shall be used to con rm the result obtained by therst two methods. After this work, it is expected that the best location would be met, after a thorough and critical comparison has been done.

1.3 Statement of the Problem

Most of the people in Obuasi are predominantly miners. This situation has occurred as a result of the mineral deposit in the land. Geographically, Obuasi is located in the Ashanti region of Ghana in sub-Sahara Africa. The mining activity has a lot of adverse e ect on the social life of the people living in the area. Notwithstanding that, several e orts have been made to control the negative impact the mining activity pose on the source of drinking water to the community. The fact still exist that people depend on stream and that has resulted in most communicable diseases such as diarrhea, dysentery, skin rashes among others. The research work is therefore an important medium to address the challenges faced by the people of the area with regards to issue of water. However, a number of factors ranging from electricity, accessibility to road, desirability of the people, and nearness to a source of river body among others, would be considered to ensuring the success of the work. In view of the above, the research was done by considering ve major towns in Obuasi after which a critical comparison was done to select the best location of the water treatment plant. These towns would be Kwabenakwa, Gausu, Akaporiso, Tutuka and Abompe. The AHP and the PROMETHEE was used to ascertain the best location for the Plant to serve most communities within the catchment area. It is expected that, policy makers and all stake holders who are connected to this issue, nds it worthy to consult this work, so as to be informed of the best location for siting the water treatment Plant in Obuasi to serve the majority of the people.

1.4 Objectives of the study

The general objectives of the study are as follows

The AHP/PROMETHEE would be used to do a comparison to have the best location.

The TOPSIS methodology would be used to con rm the best Location taking in consideration factors that a ect facility location

1.4.1 Speci c objectives

The research work would be able to help choose from the list of towns the best location from the set of nite solutions, to site the water treatment plant.

The location of the treatment plant would serve majority of the communities within the area based on the interviews before and after the location.

The indicators to measure the desirability of the facility are met. That is to mean the people living in the community respond positively to the existence of the facility.

1.5 Signi cance of the study

It is strongly believed that this thesis would:

Create a long-term solution to the water system faced by the people of Obuasi and the catchment area and to deal with problems a ecting their health and business.

make people have easy access to source of good drinking water for both domestic and commercial use and therefore will help the economy grow.

Inform policy makers about the resources available to all managers or decision makers.

give suggestions to future researchers as a base on which they can use to facilitate their work.

1.6 Methodology of the work

The health of the people who leave in obuasi are a ected by so many things including the hazards that leaving in a mining environment pose to the dwellers. It is very important to know the source of water that is used in the preparation of ltered water for sale. However, both domestic and commercial activities of the people depends largely on the water that is available for use. Besides, it very important that a water treatment plant is set up, to treat the in ow of water to various homes and work places, aimed at helping all the stake holders who need
water for various activities.

The model that the research work is subject to, was the use of the Analytical Hierarchical process (AHP) coupled with the Preference ranking organization method for enrichment evaluation (PROMETHEE) and (Technique for ordering preference of similarity in ideal solution)TOPSIS. The accessibility to road, electricity and nearness to a river source among others are very important factors to consider. Various comparisons would be done in connection with the towns that are selected for the location of the facility. Besides, the weight assign to each of the factors was considered carefully to facilitate the selection process.

This is known as pairwise comparison done with excel.

1.7 Thesis Organization

The thesis is subjected to ve (5) main chapters: Chapter 1 shows an overview of the thesis topic under consideration. This chapter, also illustrate a brief summary of facility location selection. Chapter 2 deals with the literature related to our scope of study in the thesis. Chapter 3 focuses on the solutions that have been employed in solving the identi ed problem. The methodology shall involve the use of AHP/PROMETHEE II, together with TOPSIS methods in solving the
facility location selection problem. Chapter 4 deals with data collection, analysis and results. Chapter 5 is conclusion and recommendation.

Chapter 2

Literature Review

Many researchers have done similar work in the area the researcher is seeking to do. Therefore looking at the area, there is the need to nd out the ideas put forward by others in connection with the topic under discussion.

To begin with, according to Yang and Shi(2002)the Analytic Hierarchy Process AHP has been proposed in recent literature as an emerging solution approach to large, dynamic and complex real multi-criteria decision making problems. They however stated categorically that, the result of both qualitative and quantitative analysis will be combined for each criterion at the lowest possible level in the hierarchy. In view of the aforementioned a couple of steps would have to be followed in order to arrive at the desired level and point the facility would be sited.

However, according to Honolulu(2005) he is of the view that, facility location and distribution process are two key component of a distribution system. Besides, the AHP enable the decision maker to structure a complex problem as a simple hierarchy and to evaluate a large number of often con icting quantitative and qualitative factors coupled with well-designed steps and comparison would have to be considered to make sure the site for the facility is to maximize e ciency in it use with reference to other equally better location within areas under consideration. Again, according to Vahdani et al(2013), they were of the view that, plant location problem is an important issue and has signi cant impact on e ciency of manufacturing companies. They stressed the fact that in plant location process, costs, human resource, availability of required material, climate among others were very important factors to consider in the decision making process. They however stated that plant location selection can be viewed as multiple criteria decision making (MCDM) problem.

Wang(2009) in his paper indicated that (AHP) is the quantitative calculation of decision making method to e ectively combine a quantitative judgments and decision makers. He added that the process is a complex issue for the orderly decomposition hierarchical structure through the peoples judgments on the merits of the decision-making sort programmed. The water treatment plant location shall be based on the judgments made in connection with the prevailing factors a ecting the site for the water distribution treatment plant.

In contrast to the views shared above, Heinrich(1850) rst addressed location (1780-1850), and was of the view that the creation of a complete system of agriculture land use by access to the market require a careful planing .

However, Weber(1929) suggested that industrial location was an optimal consideration of two major factors which are transportation costs and labor cost, where optimal location was the least cost production in location.

Similarly, Walter(1996) in his book o ered geometric explanation to the relative location of settlement and places and the functions of settlements.

According to Hauchbau(1998) emergency facility location problem, must minimize the maximum distance on the network across all time periods. The authors used k underlying networks to represent di erent periods and provided a polynomial time 3-approximation algorithm to obtain the solution for each problem.

On the contrary Talwar(2003) utilized a P-center model to locate and dispatch three emergency rescue helicopters to serve the growing EMS demands from accidents of tourist activities such as skiing, hiking and climbing at the north and south end of the Alphine mountain ranges. One of the model's aim, is to minimize the maximum (worst) response time and the author used e ective heuristic to solve the problem.

According to Deskin and Owen(1998) there are circumstances where the provision of a service needs more than one 'covering' facility, this occurs when facilities may not always be available. For example, assume that ambulances are being located at dispatching points in order to serve demand across an urban area, and the nearest ambulance is busy, then the next closest available ambulance, will need to be assigned to a call when it is received. If the closest available ambulance is farther than the service standard, then that demand or call for the services is not provided within the coverage standard. To handle such issues, models have been developed that seek multiple-coverage. Two examples of multiple-coverage exist, stochastic or probabilistic and deterministic.

According to Deskin(1998), he formulated a probabilistic multiple cover model called the maximal expected coverage model (MECM). Another formulation of the simple back up covering model as a good example of a deterministic cover model that involve maximizing second-level coverage was done by Hogan and

ReVelle(1986).

Toregas et al(1971) was the rst to recognize the possible need for multi-level coverage. Toregas de ned the multi-level Location Set Covering Problem (MLLSCP) as a search for the smallest number of facility needed to cover each demand, a preset number of times, where the need for coverage might vary between demands.

According to Meysam et al(2011) they are of the view that selection of the

appropriate plant location requires joint consideration of multiple alternatives and evaluation criteria because of the system complexity in manufacturing companies. They stated however that an integrated decision making methodology is a design such that, it employs the three-well known decision making techniques ,namely; Delphi, Analytic Hierarchy process (AHP) and the Preference Ranking organization method for enrichment evaluation(PROMETHEE) in order to make

the best use of information available either implicitly or explicitly.

Mohammad et al(2013) in their article selecting equipment using hybrid of AHP and PROMETHEE ranked di erent manufacturing facilities based on various criteria including price, weight ,power etc. and analyzed the results. The proposed study of this paper considered six criteria including price, weight, power, spindle, diameter and stroke for selection of manufacturing equipment.

Klose and Drexl (2005). described the types of location facility models. Among which are the continuous location models, Network location models, they however mentioned that in Network location model distances are computed as shortest paths in a graph. Nodes represent demand point and potential facility sites correspond to a subset of the nodes and point on arcs. They also mentioned mixed-integer programming models. The uncapacitated single-stage model was not left out.

Betul et al(2011) in their article‘choosing concrete production facility location using AHP and TOPSIS methodologies‘ indicated that there are four main Criteria and 14 sub-criteria to select the best location. They however added that the main criteria and their sub-criteria are Market (M), House (H) underwork (U) ,Motorway(M), Industrial plant(IP), Alternative transport way(ATW), Raw material and labour (ML), transport cost(TC), Agrega potential(AP)Reachable are size (RAS), cement Potential (CP), cost(C) water potential(WP) ,investment cost(IC), labour potential(LP), raw material transport cost(RC), labour transport cost(LTC), Transport(T)and Product transport cost(PTC). In addition, they stated that, a hierarchical structure is created or constructed in such a way that overall decision goal is at the top level; decision factors are in the middle and alternative at the bottom. The pairwise comparisons are made, and the weight found for the main criteria and sub criteria. Besides the rate should be less than 0.1.

Kumar and Kumanan(2011) in their article suggested that, Facility location decision plays a critical role in the strategic design of supply chain networks. In their paper, they proposed an integrated multi criteria decision making approach in the context of facility location selection (FLS). The main aim of the paper was to explain the use of both methods. It further explains that the AHP is used to assess how good, particular candidate location is compared to others, to help locate planning process in making an optimal selection.

Golam and Razia(2012) in their article,‘ selection of concrete production facility location integrating FUZZY AHP with TOPSIS method‘,indicated that the multidimensional, multi criteria nature of the concrete production facility location problem limits the usefulness of any particular single objective model. In this study, social, economic, environmental and transportation factors and sub criteria have been derived to make the optimal concrete production facility location selection decision more realistic and e ectual.

Ahmad et al(2012) in their article indicated that location selection is a multicriteria decision problem and has a strategic importance for many companies. They however mentioned that the FUZZY AHP is used to analyze the structure of location problem and to determine weight of the criteria and FUZZY GTMA method is used to obtain nal ranking.

Urn and Khazanah(2013) in their article enumerated some few steps that could be used when dealing with the AHP method notable among them were; Goal criteria sub criteria Alternatives fun Passion Knowledge. They also stated that to apply the AHP method one will have to establish priorities among criteria and sub criteria .The AHP can be used to help us address other case which required complex decision process.

According to Vasant(2009) in the article plant location Decision ,stated that in the location of a facility, the site size, cost Air, rail, highway and water way systems Zoning restrictions, Nearness of services/supplies needed environmental impact issues are part of the many things to consider when siting facility like a plant .In addition, he added that proximity to suppliers, perishable goods, bulky product among others are part of the factors to consider when setting up such facilities. The location break-even analysis method of cost-volume analysis is used for industrial locations. However, the three steps in the method determine xed and variable costs for each selected location with lowest total cost for expected production volume.

Hunkar(1970) in his article‘ factors responsible for plant location in operations and materials management‘ stated that plant location signi cantly impact cost as well as the speed with the rm can supply products where the end users will be in need of them . Furthermore, changing the location plant is very di cult and costly. Mistakes in the selection process can have a long-term rami cation. Sigit(2011) stated in their article that in TOPSIS method, the ideal values are set as the maximum value which belongs to an alternative for a particular criterion, depending upon the optimization scheme example minimization or maximization comparison of each alternative to the other for each and every di erence between the other alternative and the one to be compared.

Leigh and Mccarthy(2010) in their thesis, 'Analysis of alternative water sources for use in the manufacture of concrete' indicated that measurements of the indicators to be used to determine and monitor changes in whether the quality of the water is suitable for use in concrete production.

The technique for order of preference by similarity to ideal solution (TOPSIS) is a multi-criteria decision analysis method, which was originally developed by Hwang(1981). TOPSIS is based on the concept that the chosen alternative should have the shortest geometric distance from positive ideal solution and the longest geometric distance from the negative ideal solution. It is a method that compares a set of alternatives by identifying weight for each criterion and calculating the geometric distance between each alternative and the ideal alternative which is the best score in each criterion.

Schilling et al(1992) stated that Fundamental to the modeling of location is some measure of proximity, while the speci c point-to-point distance (or time) is often used. They however continued that, the norm of partitioning inter-point distances based on some distance standard that has been employed extensively in the location literature or over a quarter of a century. They also added that decision makers often base decision on the 'satisfactory' rather than minimizing total travel distance, for example, a distance standard might be set which de nes satisfactory service.

A deterministic p-median model with the objective of minimizing the distance travelled by a number of users to xed public facility such as banks, medical or day-care centers was formulated by Carbone(1974). He indicated that there is uncertainty in recognizing the number of users at each demand node. He further extended the deterministic p-median model to a chance constraint model. The model seeks to minimize a threshold and meanwhile ensure the probability that the travel distance below the threshold is smaller than a speci ed level alpha.

Serra and Marianov(1994) implemented a p-median model and introduced the concept of regret and minmax objectives when locating re station for emergency services in Barcelona. They stated categorically in their model, the issue of locating facility when there are uncertainties in demand, travel time or distance. In addition, the model uses scenarios to incorporate the variation of uncertainties and seek to give a compromise solution by minimizing the maximum regret over the scenarios. P-median models have also been extended to solve emergency service location problems in a queuing theory context. An example is the stochastic queue median (SQM) model due to Beran et al (1985). The SQM model

intends to reposition mobile servers such as emergency response units optimally to demand points and locate the facilities so as to minimize average cost of response tremendously.

According to Paluzzi(2004), he discussed a p-median based heuristic location model for placing emergency service facilities for the city Carbondale, IIlinois. In his work, the goal of his model was to determine the optimal location for placing a new re station by minimizing the total aggregate distance from the demand sites to the re station. A technical comparison of his result with the results from other approaches and comparison validated the usefulness and e ectiveness of the p-median based on location model. Reposition of Emergency service (EMS) units such as ambulances during emergencies was one major application of the p-median models.

A mathematical model to select the optimal alternative for an integral plan to deserti cation and erosion control for the Chaco area in Salta province (Argentine) was proposed by Grau(2010). They used three multi criteria decision

methods ELECTRE, PROMETHEE and AHP for di erent sub zones which were established based on previous studies. In the development of the model, they took into consideration economic, environmental, cultural and sociological criteria. Their multi-criteria model to select among di erent alternatives to prepare an integral plan to solve this problem in each area has been discussed thoroughly, taking into account eight criteria and six alternatives. Their results indeed, revealed a high level of consistency among the three di erent multi criteria methods in spite of the complexity of the system studied.

Nemery and Lamboray (2007) established a new sorting method (Flow Sort) based on the ranking methodology of PROMETHEE for assigning actions to completely ordered categories, de ned either by limiting pro les or by central pro les. The Flow Sort assignment rules were based on the relative position of an action with respect to the reference pro les in terms of the incoming, leaving and or net ows. They added that for a better understanding of the issues involved, a graphical representation was given to further explain the concept. An explicit relationship between the assignments obtained when working either with limiting or central pro les was formalized. An empirical comparison with ELECTRE-TRI was made to compare the resulting assignments nally.

Enterprise technology innovation project method based on PROMETHEE was appraised by wen-jun et al(2008). With regards to the question on the choice of the iron and steel enterprise technology innovation project, their research indicated the technology innovation project appraisal index system on the iron and steel enterprise. As mentioned, they used the PROMETHEE method a class of outranking methods in multi criteria analysis, and it ranked various projects reasonable with the inde nite weight information. When compared with the TOPSIS method, it illuminated that the conclusion of this method was valid and credible.

Hermans et al.(2006) indicated in their work that ,the collaborative environmental planning in river management in the white river water shed in Vermont adopted the PROMETHEE as a multi criteria decision analysis methodology. Their research presented the frame work and results of a structured decision process using the PROMETHEE. The PROMETHEE was used to frame multi-stakeholder discussions of river management alternatives for the upper white river of central Vermont, in the North eastern United States. Stakeholders met over ten (10) months to create a shared vision of an ideal river and its services to communities, develop a list of criteria by which to evaluate river management alternatives, and elicit preferences to rank and compare individual and group preferences. The Multi-criteria decision Aid (MCDA) procedure helped to frame a group process that made stakeholder preferences explicit and substantive discussions about long term river management possible.

Kodikara(2008) in his thesis on multi objective optional operation of urban water supply systems made an appropriate use of the PROMETHEE methodology. In Kodikara s research he attempted to develop and assess the potential of a generic decision support framework to assist in evaluating alternative operating rules for multi purpose, and multi reservoir urban water supply systems.

A multi criteria decision making methods PROMETHEE and Geometric Analysis interactive aid (GAIA) to air quality in the micro environment of residential houses in Brisbane, Australia was applied by Ayoko et al(2004). Their study mainly dealt with the application of the multi criteria decision making methods, PROMETHEE and GAIA, to indoor and outdoor air quality data. In their work, a total of Fourteen (14) residential houses in a suburb of Brisbane, Australia were investigated for twenty-one (21) air quality in uencing criteria, it included the characteristics of the houses as well as the concentrations of volatile organic compounds, fungi, bacteria, sub micrometer, and super micrometer particles among others in their indoor and outdoor air samples. Ranking information necessary to select one house in preference to all others and to assess the parameters in uencing the di erentiation of the houses was found with the aid of PROMETHEE and GAIA. The outcome of their analysis indicated that there was no correlation between the rank order of each house and the health complaints of its dwellers. Patterns in GAIA plots showed that indoor air quality in these houses was strongly based on the characteristics of the houses (construction materials, distance of the house from a major road, and the presence of an in built garage). Besides, marked similarities were observed in the patterns obtained when GAIA and factor analysis were applied to the data. They however stated categorically that, the potential of PROMETHEE and GAIA to provide information that could assist source apportionment and elucidation of e ective remedial measures for indoor air pollution.

The World Wide Web has become an important tool for business, According to Villota(2009), millions of websites had been developed and so inherently they could come across every kind of website from easy to hard-to-use. The authors added that there were some so-called usability criteria, which should be respected by web designers in order to make websites useful. As a result, using a multicriteria decision making approach, they evaluated the performance, based on seven (7) usability criteria, of ve (5) websites from which one could buy books online. They explained that the complexity of multi-criteria decision making was based on the fact that those multiple criteria were often contradicting with each other, and so a solution that optimizes every criterion simultaneously, or an ideal solution, was generally unfeasible. In that situation making a decision implied giving an answer which without being optimal was still satisfactory. Considering usability as a subjective matter, they used two well-known methodologies that deal with this issue: Analytic Hierarchy Process (AHP) and PROMETHEE. Through PROMETHEE they related the preference of a decision maker with
specially de ned criterion functions.

Barton and Baynon(2009) stated in their work that a PROMETHEE based uncertainty analysis of UK police force performance rank improvement was designed for a periodic comparison of the police forces in the UK with each other in terms of performance by both government and non-government bodies. In their study, they demonstrated the employment of PROMETHEE in an investigation of the targeted performance rank improvement of individual UK police forces. The graphical representations presented o ered an insight into the implications of such a PROMETHEE based series of perceived improvement analysis. The goals of their study were two folds, namely to exposit PROMETHEE based uncertainty analysis in rank improvement and secondly, how the subsequent results could form part of the evidence to aid in their performance strategies.

The lean improvement of the chemical emissions of motor vehicles based on preference ranking PROMETHEE uncertainty analysis has been considered by Baynon and wells(2006). The authors observed that the motor vehicle had provided mobility and individual freedom for millions of people. Vehicles embodied the dilemma of contemporary industrialization in that the environmental costs of automobility were equally large. Their non country speci c study under took a PROMETHEE-based preference ranking of a small set of motor vehicles based on constituents of their exhaust emissions. As a model of an interested party's preference ranking of the motor vehicles, the subsequent uncertainty (sensitivity) analysis considered here, related to what minimal (lean) changes would be necessary to the emissions of a vehicle so that their preference ranking is improved. For a particular manufacturer, it could identify the necessary engineering performance modi cation to be made to improve their perceive consumer based ranking. This was compounded by a further consideration of di erent levels of importance conferred on the criteria (vehicle emissions) and analogue analysis undertaken. The visual elucidation of the results rankings and changes to criteria values, o ered a clear presentation of the ndings to the interested parties.

Chapter 3

Methodology

This chapter of the thesis shall carefully consider the factors that a ect facility location and also a concise history of AHP/PROMETHEE II and TOPSIS ranking methodology for facility location selection.

3.1 Factors that in uence facility location

The desirability of a location to site a facility for both domestic and commercial use for all stake holders directly or indirectly connected, depends largely on the factors that a ect the environment within which the facility is positioned, in conjunction with their potential impact on corporate objectives and operations associated with the facility. There are quiet a considerable number of factors that has to be discussed and these include: proximity to customers, nearness to market, availability of Electricity, road network, community desirability and other facilities. The facility location of a water treatment plant to serve the people of Obuasi and the catchment towns is a very important issue that cannot be overlooked since there are quiet a lot of people within the area without access to good drinking water.

3.1.1 Proximity to consumers

Siting a facility close to customers is an important factor to consider due to the increase in the demand for services. It also ensures the quick delivery from demand point to respective places. Here the ability of the researcher to nd the best location to site the facility shall increase the delivery of water to the demand point and quarters which are in most need of it.

3.1.2 Nearness to the markets

Locating a facility such as the water treatment plant near a market is a very important issue to consider since activities that go on in the market needs the use of water. However, the rampant re outbreak in our environment of which the market is the most vulnerable among all, needs to be tackled with immediate e ect and with the entire agency .The existence of a re hydrant in the market close to the water treatment plant shall ensure a quick extinguishing,if there is any.

3.1.3 Availability of Electricity

Energy is a vital factor to consider when choosing a site for location of a facility. Source of power for the operations of the water treatment plant is indeed very important. The amount of power required for the operations of the plant should be huge enough to sustain the e ectiveness. Such an important facility needs thousands of kilowatts of power.

3.1.4 Road network

The road network within the Obuasi Township is a very important issue to consider when setting up a facility such as the water treatment plant. The various towns chosen have their respective distances relative to the possible site for the location of the facility. A good road from the facility shall enhance the evenly distribution of the water, to all the demand points within the locality and the catchment towns.

3.1.5 Community desirability

The community within which the facility is to be sited plays a major role in the process of evaluation of the location to site the plant. There are many environmental concerns associated with facility location. Therefore, decision makers consider it important to have a positive community attitude. Hence, this assumes that community attitude will have a positive impact on the facility location. A careful survey should be conducted to prove beyond all reasonable doubt that the people in the community approves of the existence of such a facility.

3.1.6 Other facilities

When setting up such a facility, it is important to consider other facilities whose operations are close to the one you intend to set up or interdependent on the facility that is to be set up. Serious caution must be taken into consideration to facilitate process of siting the facility.

3.2 Facility location model

A thorough search on literature for this topic has been done and several models have been formulated and applied to the facility location problems over the last few decades. The level of di culty that arises when setting up this facility depends largely on the quantitative and qualitative factors in uencing location of the facility. However, others have resorted to the use of several algorithm formulations in di erent setting including the Private and public sector of the economy. The following; Industrial plant location, retail facilities, telecommunication mast in the private sectors as well as the schools, banks, health centers, ambulances, and hospitals in the public sectors are examples of facilities to be considered when dealing with facility location. In this thesis, the researcher's focus is on the public sector dealing with the location of a water treatment plant intended to help the people leaving in the community. The presence of such a facility shall help reduce the risk that is associated with the stay in this environment. Besides, the provision of these facilities e ectively, is a complex issue that specially depends on some factors and most especially on the geographical location of the facility. This work is intended to use combinatory methods including the Analytic Hierarchical Process (AHP), Preference ranking Organizational Method for Enrichment Evaluation (PROMETHEE) and the Technic for ordering preference similarity to ideal solution (TOPSIS) methods to select the best location for positioning the water treatment plant that could distribute water to all places that is needed for both domestic and commercial use. The location of a facility is aimed at improving services for customers and the entire populace whose location from that point may di er in terms of distances. The provision of services exists for a number of largely dispersed sites that need the facility most importantly. Therefore, it is a very important issue to consider when siting a facility like the water treatment plant at Obuasi. There are however a number of reasons that will have to be considered carefully when attempting to locate a facility in a community. Factors such as time, distance for travel and cost are very much indeed critical to study in ones bid to locate this important facility if the intended e ect is to be realized in future. Examples of location models are the P-Median Problem (PMP), P-Center Problem (PCP), Location Set Covering Problem (LSCP) and Maximal Covering Location Problem (MCLP).

3.3 The P-median Problem

The facility location models, used widely over the years date back from the research done by Alfred weber, who derived a method for placing a facility at a location that minimized the distance traveled by some set of customers (Weber, 1909). He considered the environment to be a continuous two-dimensional plane, where the facility could be placed anywhere on this surface. However, in many cases stake holders or policy planners were critically informed of the best location for putting up a facility. Alfred weber's technique contributed immensely, since a qualitative means to e ciently place a facility and also provide a strategic location and frame work for many other location models, aimed at the world of
Business is achieved.
minimize:

$$\sum_{j\in J}\sum_{i\in I} h_i d_{ij} y_{ij} \quad (3.1)$$

Where h_i represent the weight assigned to the alternative at node(i).

d_{ij} represent the relative distance of the facility(i) to the demand point(j). y_{ij} represent the relative importance between two factors(i) to a facility(j) Hence the product of h_i, d_{ij}, y_{ij} is the demand weighted total distance travelled

subject to

$$\sum_{j\in J} X_i = P \tag{3.2}$$

$$\sum_{j\in J} y_{ij} = 1, \forall_i \in I \tag{3.3}$$

$$\sum_{j\in J} y_{ij} - x_i \leq 0, \forall_i \in I, \forall_j \in J \tag{3.4}$$

$$W - \sum_{j\in J} h_i d_{ij} y_{ij} \geq 0, \forall_i \in I \tag{3.5}$$

Where W is the weight assigned to the facility.

$$X_j \in 0,1, \forall_j \in J \tag{3.6}$$

$$y_{ij} \in 0,1, \forall_i \in I, \forall_j \in J \tag{3.7}$$

The objective function(3.1) minimizes the maximum demand-weighted distance between each demand node and its closest open facility. Constraint(3.2) stipulates that p facilities are to be located. Constraint set (3.3) requires that each demand node be assigned to exactly one facility. Constraint set(3.4) restricts demand node assignment only to open facilities. Constraint (3.5) de nes the lower bound on the maximum demand-weighted distance, which is being minimized. Constraint set(3.6) established the sitting decision variable as binary. Constraint set(3.7)
can be replaced by

$$y_{ij} \geq 0, \forall_i \in I, j \in J, \tag{3.8}$$

because constraint set (3.4) guarantees that

$$y_{ij} \leq 1. \tag{3.9}$$

If some

$$y_{ij} \tag{3.10}$$

are fractional, we can simply assign node I to its closest open facility.

For xed values of p, the vertex p-center problem can be solved in O (Np) time since we can enumerate each possible set of candidate locations in this amount of time. Clearly, even for Moderate values of N and p, such enumeration is not realistic and more sophisticated approaches are required. For variable values of p, the problem is NP-hard (Garey and Johnson, 1979)

If integer-valued distances can be assumed, the unweighted vertex or absolute p-center problem is most often solved using a binary search over a range of coverage distance (Handler and Mirchandani, 1979; Handler, 1990) for each coverage distance, a set covering distance is the solution to the p-center problem. Deskin (2000) has recently shown how the maximal covering model can be used e ectively in place of the set covering as a sub-problem in solving the unweighted vertex p-center problem.

3.4 P-center Problem

The problem associated with the minimization of the maximum distance that demand is from its closet facility given that we are siting a pre-determined number of facilities is addressed by the p-center problem (Hakimi, 1964, 1965). The basic model has several possible variations that can be employed. The

p-center problem restrict the set of Candidate facility sites by vertex to the nodes of the network while the absolute p-center problem allows the facilities to be anywhere along the arcs. There are two aspects and can therefore be classi ed as weighted or unweighted depending on the situation. Taking into consideration the unweighted problem, all demand nodes are equally treated. Whiles with the weighted model, the distance between demand nodes and facilities are multiplied by a weight associated with the demand node. For instance, this weight might indicate how important a node is with reference to the demand point or in contrast, the level of its demand. With reference to our earlier de nition and the decision variables outlined below

W= the maximum distance existing between the demand node and a facility to which it is assigned

$$y_{ij} = 1 \tag{3.11}$$

if demand node i is assigned to a facility at node j

0 if not The formulation of the P-center problem is as follows

Maximize

$$W \tag{3.12}$$

Subject to:

$$\sum_{j \in J} x_j = p \tag{3.13}$$

$$\sum_{j \in J, i \in I} y_{ij} = 1, \forall_{j \in J}, \forall_i \in I \tag{3.14}$$

$$y_{ij} - x_i \leq 0, \forall_{j \in J}, \forall_i \in I \tag{3.15}$$

$$W - \sum_{i \in I, j \in J} h_i d_{ij} y_{ij}, \forall_{j \in J}, \forall_i \in I \tag{3.16}$$

$$x_i \in 0,1, \forall_i \in I \tag{3.17}$$

$$y_{ij} \in 0,1 \forall_i \in I, \forall_j \in J \tag{3.18}$$

The objective function (3.12) minimizes the maximum demand-weighted distance between each demand node and its closest open facility. Constraint (3.13) stipulates that p facilities are to be located. Constraint set (3.14) requires that each demand node be assigned to exactly one facility. Constraint set (3.15) restricts demand node assignment only to open facilities. Constraint (3.16) de nes the lower bound on the maximum demand-weighted distance, which is being minimized. Constraint set (3.17) established the sitting decision variable as binary. Constraint set (3.18) can be replaced by

$$y_{ij} \geq 0, \forall_i \in I, \forall_j \in J \quad (3.19)$$

because constraint set (3.14) guarantees that

$$y_{ij} \leq 1 \quad (3.20)$$

3.5 Covering models

The next identi ed model in consideration is the covering model. Covering models are the widely used location models for solving the emergency facility location problem. In this discussion, the objective here is to provide covering to the demand points. A demand point is considered as covered only if a facility is available to service the demand point within a coverage distance limit which normally referred to as a critical distance. At the heart of the set covering and maximal covering model is the notion of covering. Hence the radius of the demand point that is the places that will be receiving water is captured.

3.5.1 Location Set Covering Model

To nd a set of facilities with minimum cost from among a nite set of candidate facilities so that each demand node is covered by at least one facility is the set covering problem. Location set covering problem involves nding the smallest number of facilities and their locations so that each demand is covered by at least one facility underscored by Toregas(1970). The location set covering problem does not specify a prior distance covering within which a demand is covered. However, the Maximal Covering Location problem nds the facilities and their locations such that each demand is not farther than a pre-speci ed distance or time from its closest facility. A demand is covered if one or more facilities are located within the maximum distance or time

The formulation of the model is as follows:

Minimize

$$Z = \sum x_j \quad (3.21)$$

$$j \in J$$

Subject to

$$\sum_{j \in N_i} ,\forall_{i \in I} \quad (3.22)$$

$$x_j = 0,1,\forall_j \in J \quad (3.23)$$

J = set of eligible facility sites (indexed by j) I= set of demand nodes (index by i)

$$x_j = 1, \quad (3.24)$$

if facility is at location J

0 if otherwise

$$N_i = JId_{ji} \leq S \quad (3.25)$$

$$d_{ji} = \quad (3.26)$$

Shortest distance from potential facility location j to demand i,whereas S= distance standard for coverage.

However,

$$N_i \quad (3.27)$$

represent the set of all those sites that are candidates for potential location of facility, found within the distance S of the demand node i. However, demand node i becomes covered if a facility is located in any of them. The objective (1) minimizes the number of facilities required. Constraints (2) state that the demand at each node i must be covered by at least one server located within the time or distance S.

Toregas and ReVelle (1973)also underscored the fact that, the solution to this model can be found easily, solving its linear programming relaxation, with occasional branch and bound applications. Before solving, its size can be reduced by successive row and column reductions.

3.5.2 Maximum covering location

The set covering has associated problems, one of which is that the number of facilities that are needed to cover all demand nodes is likely to exceed the number that can actually be built due to budget constraints and other related issues. Furthermore, the set covering model treats all demand nodes identical. Under certain conditions and budgetary constraints it is appropriate to x the number of facilities that are to be located and then maximize the number of covered demands.

Church and ReVelle (1974) formulated a Maximum Covering Model as follows:

let

$$h_i = \qquad (3.28)$$

demand at node i

p=number of facility sites

Decision variables be

$$Z_i = 1 \qquad (3.29)$$

if node i is covered

0 if not

The Maximum Covering Location Model is formulated as follows

Maximize

$$\sum_i h_i z_i \quad (3.30)$$

Subject to

$$Z_i \leq \sum_j a_{ij} x_j, \forall i \qquad (3.31)$$

$$\sum_{j} x_j \le p \qquad (3.32)$$

$$x_j = 0.1 \qquad (3.33) \quad Z_i = 0.1 \quad (3.34)$$

The objective function 3.30 maximizes the number of covered demands. Constraints 3.31 state that demand node i cannot be covered unless at least one of the facility sites that cover node i is selected. But, the right-hand side of constraints 3.32 which is

$$\sum_{ij} x_j \qquad (3.35)$$

is identical to the left-hand side of constraints 3.32

$$\sum_{j} a_{ij} x_j \qquad (3.36)$$

gives the number of selected facilities that can cover node i, the constraint 3.32 stipulates that we locate not more than p facilities. Constraint 3.30 will be binding in the optimal solution. Constraints 3.33 and 3.34 are the integrality constraints on the decision variables.

3.5.3 Maximum Expected Covering Location Model

Daskin (1983) proposed MEXCLP as extension to the Maximal Covering Location Problem (MCLP) formulated by Church and ReVelle (1974), (Chiyoshi et al 2003b). This was mainly to account for possibility of unavailability due to a congested system. The interest here is for demand to be covered by a located facility that is available when a demand for service arises. The approach attempted to maximize expected coverage given that the servers are busy and unavailable with a calculable system wide probability, P (Daskin, 1983). Three (3) simplifying assumptions were made by Daskin (1983) when he formulated the MEXCLP (Chiyoshi et al., 2003b)

Server operate independently.

Each server has the same busy probability.

Server busy probabilities are invariant with respect to their location.

Again a substitution heuristic was developed by Deskin (1983) he however tested it on a fty- ve (55) node network problem.

The MEXCLP maximized the expected value of population coverage within the time standard, given that p facilities are to be located on the network. Daskin computed the increase in the expected coverage of a demand, when a

$$k^{th} \tag{3.37}$$

server is added to its neighbourhood, which turns out to be just

$$(1-q)q^{k-1} \tag{3.38}$$

Then, the expected coverage for all possible number of servers' k at each neighbourhood, and for all demand nodes weighted by their demand, is maximized:

Maximize

$$Z = \sum_{i \in I} \sum_{k=1} a_i (1-q) q^{k-1} y_{ik} \tag{3.39}$$

Subject to

$$\sum_{k=1} y_{ik} \leq \sum_{j \in N_i} x_j, \forall_i \in I \tag{3.40}$$

$$\sum_{j \in J} x_j = p \quad (3.41)$$

$$y_{ik} = 0,1 \forall_{i,k} \quad (3.42)$$

$$x_j = intergers, \forall_j \quad (3.43)$$

Such that;

$$y_{ik} \quad (3.44)$$

is one if node i has at least k servers in its neighbourhood, zero otherwise,

$$x_j \quad (3.45)$$

is the number of servers at site j, and

$$n_i \quad (3.46)$$

is the maximum number of servers in

$$N_i \quad (3.47)$$

There are two main constraint, the rst constraint indicate that the number of servers covering demand i is bounded above by the number of servers sited in the neighbourhood. The second constraint limits the number of servers to be deployed. Declining weights

$$(1 - q)q^{k-1} \quad (3.48)$$

on the variables

$$y_{ik} \quad (3.49)$$

make unnecessary any ordering constraints for these variables, and help to the integrality of these variables in the solution, if the linear relaxation of the model is solved. Daskin proposed a heuristic method of solution of the MEXCLP, which gives solution for the system for di erent ranges of values of q.

However, according to Toregas and revelle(1972) the belief that mathematical location model can identify 'optimal' location pattern rest on the basis that some realistic objective can be identi ed and by some measure quanti ed. Unlike private location analysis the objective of public facility location are more di cult to embrace and to quantify. The di culty in de ning direct measures in public objectives has resulted in the search for surrogate measure with which the decision maker may be comfortable. They stated however that two surrogate that has attracted attention are ;(1) Total weighted distance or time for travel to the facility.(2) the distance or time that user most distant from that facility would have to travel to reach the facility

3.6 Brief History of AHP, PROMETHEE and TOPSIS

3.6.1 Analytic Hierarchy Process (AHP)

The Analytical Hierarchical Process was originally developed by Prof. Thomas Saaty in the year 1980, to enable decision making situation characterized by multiple attribute and alternatives. AHP is one of the multi-criteria decision making technique. In most cases the AHP has been applied successfully in many areas in dealing with issues of decision making. Besides, the AHP is a method to derive ratio scale from paired comparisons. The Analytical hierarchy process (AHP) provides an intensive framework for structuring a decision problem into a form that can be managed carefully. However, AHP is a prioritized weighting of each decision alternative. The AHP converts these evaluations to numerical values that can be processed compared over the entire range of the problem. A weight is assign to each element of the hierarchy, allowing diverse and often incommensurable elements to be compared to one another in a rational and consistent way. The AHP begins with a rst step, by modeling the problem as a hierarchy. The problem at stake is resolved into a hierarchy that can best be explained. The process is made up of an overall goal at the highest level, a number of available options or alternatives for getting to the goal and a group of factors or criteria that connect the alternatives to the goal.

3.6.2 PROMETHEE

The PROMETHEE methodology is made up of six outranking methods,
PROMETHEE namely the PROMETHEE I, PROMETHEE II, PROMETHEE III, PROMETHEE IV, PROMETHEE V and PROMETHEE VI stated according to Behzadian et al., 2010. PROMETHEE I and PROMETHEE II, respectively are concerned with partial and complete ranking of alternatives and were propounded by Brans in the year 1982 and presented at a conference organized by Nadeau and Landry at the University Laval, Quebec, Canada (Brans, 1982). Subsequently, PROMETHEE III for ranking based on interval, PROMETHEE IV for complete or partial ranking of alternatives were simultaneously developed, the set of viable solutions is continuous and was developed by (Brans et al., 2011). The last two methodology PROMETHEE V for multi-criteria problems involving segmentation constraints and PROMETHEE VI for the representation of the human brain were proposed between 1992 and 1994 (Brans et al., 2010). In addition to the above mentioned criteria, others are multi criteria decision aids (MCDA) which include the PROMETHEE, besides that the group decision support system (GDSS) for group decision making (Brans et al.2010), and the visual interactive module, the geometrical interactive analysis aid(GAIA) meant for pictorial representation to complement the algebraic methodology. These were developed to facilitate the analysis of more complex decision making.

3.7 Overview of Methodologies

3.7.1 The AHP method

The AHP method was developed by Prof. Thomas Saaty in the year 1980 to help resolve the problem that relate to complex decision making in our society. The process makes it possible to incorporate judgments on tangible qualitative

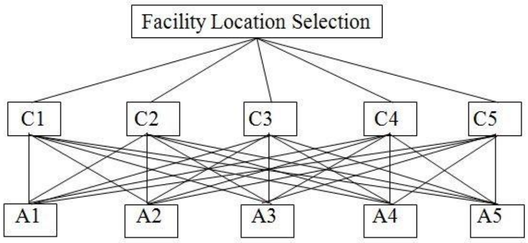

Figure 3.1: the negative outranking ow (Entering ows)

criteria alongside tangible quantitative criteria (Badri 2001). The AHP method is made up of three main principle which include, rst the structure of the model, second; comparative judgments of the alternative and the criteria, third synthesis of the priorities. To begin with, a complex decision problem is structured as a hierarchy, such that an MCDM problem is broken down into a hierarchy of interrelated decision element. The overall aim of the AHP methodology is to structure available materials and facts which include the objectives, criteria and available alternatives in the form of a pyramid where the overall goal is situated at the topmost part of the structure, whiles multiple criteria which de nes alternatives is found at the middle and decision alternatives at the bottom as shown in gure 3.1 Figure 3.1: the Hierarchical levels associated with the selection of a location for a Facility. The next stage to consider when dealing with the AHP is done in such a way that the decision makers do a critical comparison of all the alternatives in a systematic order, comparing the entire alternatives one after the other to make sure the best decision is reached. In that regards, the decision makers must pay attention to the critical element above them in the hierarchy. The AHP convert the evaluations into a numerical value that can assist the decision makers to process and compare over the entire range of problems. A numerical weight is assigned to each of the alternative element in the hierarchy, which helps in the analysis, interpretation and incorporation of the entire alternative with each and every other proposed ones which can compete equally with possible preferred

criteria.

It is expected that at the nal stage of this process, the numerical values assigned to the criteria are calculated with respect to each of the entire decision alternatives. These values denote the relative strength of the decision alternatives aimed at attaining the highest decision goal, so they make room for the direct consideration of the various actions taken in connection with the most desired site for the location of the water treatment plant. The relative judgments are assigned an integral value on a scale. Saaty's de nition of a scale was adopted in this work. The scale and their corresponding importance are outline below

on table 3.1 From the table, a de ned number of alternatives A, made up

Table 3.1: Rating Scale developed by saaty(1980)

(Scale)	Relative importance of the element	Explanation
1	equally important	i and j are equally important
2	-	
3	Moderately important	i is moderately more important than j
4	-	
5	Strongly important	i is more strongly important than j
6	-	
7	Very strongly important	i is Very strongly more important than j
8	-	
9	Extremely important	i is Extremely more important than j
2,4,6,8	Intermediate values	used when a compromise is needed

of $A_1, A_2, A_3 \ldots\ldots A_n$ and the corresponding Decision Criteria C, made up of $C_1, C_2, C_3 \ldots\ldots C_n$

are outlined. The corresponding data of decision matrix are also given as follows; $a_{11} = (A_1, C_1), a_{12} = (A_1, C_2), a_{13} = (A_1, C_3)$ $a_{14} = (A_1, C_4), a_{1n} = (A_1, C_n)$ $a_{21} = (A_2, C_1), a_{22} = (A_2, C_2)$ $a_{23} = (A_2, C_3)$ $a_{24} = (A_2, C_4) \ldots, a_{2n} = (A_2, C_n)$

The pairwise comparison is made up of $a_{n \times n}$ square matrix which is stated mathematically,such that n denote the alternatives

or criteria.

However, Judgment weights are the estimated element of the matrix, the corresponding importance associated with it. For instance the pair wise comparison matrix A, such that the element a_{ij} of the matrix is the relative importance of the i^{th} factor with respect to the j^{th} factor and reciprocals are assigned automatically as

$$A = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/a_{1n} & \cdots & \cdots & 1 \end{bmatrix}$$

Calculating the weight and determining how consistent each level is in the matrix. The rst step is usually done such that all the values in each row of the comparison matrix are added. The next thing to do is to divide the row sum by the total

sum. The implied weight is given by the formula.

$$Weight = \frac{rowsum}{totalsum} \tag{3.50}$$

The next step is to nd the relative priorities of criteria or alternatives. The eigen vector theory is used to work out the relative priorities. The consistency check should be done at each stage of the selection process. The Consistency Index (CI), Random Consistency Index (RI) and Consistency Ratio (CR) are three component used to analyze the consistency. The element calculation is done by

the following technique.

Table 3.2: Random consistency index(RI)

	1	2	3	4	5	6	7	8	9	10
	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

A critical comparison of the Random consistency index (RI) in the Table 3.2 above and the CI value is done systematically. However, calculated averages of CI's of many thousand matrices of the similar order whose entries were generated randomly from the scale 1 to 9 with reciprocal e ect is seen on Table 3.2. Saaty in the year 1980 developed the simulation results of RI for matrices of size 1 to 10 and are given in Table 3.2. The ratio of CI and RI for the same order matrix is called the consistency ratio CR. Besides, the consistency ratio (CR) is given by

$$CR = \frac{CI}{RI}$$

Such that $CR \leq 0.1$

In most cases, a consistency ratio of 10%

(0.1) and below is basically convenient for assessment. If it is observed that there are inconsistencies of judgments occurring within a matrix, then evaluation

process should be done and improved upon until the best is obtained. At the nal stage of the calculation, the overall preference matrix would be constructed by nding the product of all the weights and factors, hence the results obtained are added to get the composite score of each factor.

3.7.2 The PROMETHEE Method II

The PROMETHEE method is a special one that is used for outranking of most multi-criteria decision making problems that occur in our society. Brans and Vincke in 1985 developed the PROMETHEE (preference ranking organization method for enrichment evaluation) method. The PROMETHEE I method can

provide the partial ordering of the decision alternatives, whereas, PROMETHEE II method can derive the full ranking of the alternatives. In this work, the combination of AHP/PROMETHEE II methods together with TOPSIS

methodology are employed to obtain the full ranking of the alternative facility location to site water treatment plant. The steps as applied in PROMETHEE II method are out as outlined below:

Step 1: to begin with, normalize the decision matrix using the following equation:

$$R_{ij} = \frac{[X_j - minXj]}{[maxX_j - minX_j]}, i = 1, 2, ..n, j = 1, 2, ...m \quad (3.51)$$

Such that X_{ij} is the performance measure of i^{th} alternative with respect to j^{th} criterion.

For non-bene cial criteria, Eqn. (3.64) can be rewritten as follows;

$$R_{ij} = \frac{[maxX_j - X_j]}{[maxX_j - minX_j]} \quad (3.52)$$

Step 2:The evaluative di erences is calculated of i^{th} alternative with respect to other alternatives. This step includes the calculation of di erences in criteria values between di erent alternatives pairwise.

Step 3: Evaluate the preference function, $P_j(A_k,A_i)$.

Brans and Mareschal (1994) proposed six types of generalized preference functions. However, these preference functions must include the de nition of some preferential parameters, such as the preference and indi erence thresholds. However, in real time applications, it may be di cult for the decision maker to specify which speci c form of preference function is suitable for each criterion also to determine the parameters involved. To avoid this problem, the following simpli ed preference function is adopted here:$P_{ij}(A_k,A_i) = 0$ if $R_{kj} \leq R_{ij}$

$$P_{ij}(A_k,A_i) = R_{kj} - R_{ij} if R_{kj} \geq R_{ij} \quad (3.53)$$

Step 4: Find the aggregated preference function, considering the criteria weights. Aggregated preference function,

$$\Pi(A_k,A_i) = [\sum_{i=1} W_{ij} \times P_j\Pi(A_k,A_i)]/[\sum_{j=1} W_j] \quad (3.54)$$

Such that w_j is the relative importance (weight) of j^{th} criterion.

Step 5: Find the leaving and entering outranking ows as follows:

With reference to the preference function $\pi(A_k,A_i)\forall A_k,A_i \in A$, such that 'A' represent a nite set of alternatives and indicates the degree of preference expressed by the decision maker for the alternative A_k over alternative A_i for all

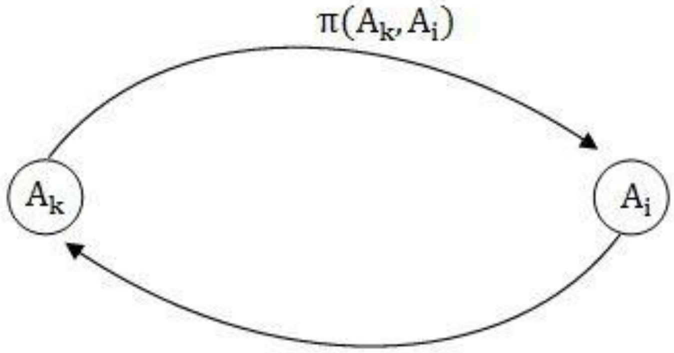

Figure 3.2: Outranking ow Relation
$\pi(A_k,A_i)$

the criteria. Contrary to that, there are some criteria too in which the alternative A_i may be preferred to the alternative A_k giving rise to the preference function $\pi(A_i,A_k)$. However, his shows how two alternatives have a comparative advantage over each other over a given nite criteria.

Besides, the two indices $\pi(A_k,A_i)$ and $\pi(A_i,A_k)$ connect every pair of alternatives such as (A_k,A_i), to each other. Such a connection or relation is known as the outranking relation.

The relation is often represented graphically, by two nodes showing the two alternatives linked to each other by a corresponding two arcs each for a preference index.

In Figure 3.2 below As indicated in the gure above, the alternatives A_k and A_i in rings are the nodes. The preference index $\pi(A_k,A_i)$ which links node A_k to node A_i as indicated by the arrow of the upper arc of Figure 3.2, depict the magnitude of the preference of the alternative A_k over A_i. The preference function $\pi(A_k,A_i)$ on the other hand, connects node A_i to A_k and is indicated by the arrow of the lower arc of Figure 3.2 showing the magnitude of preference of the alternative to

A_i to A_k.

In addition, each alternative faces (n 1) number of other alternatives. The leaving ow expresses how much an alternative dominates the other alternatives, while the entering ow shows how much an alternative is dominated

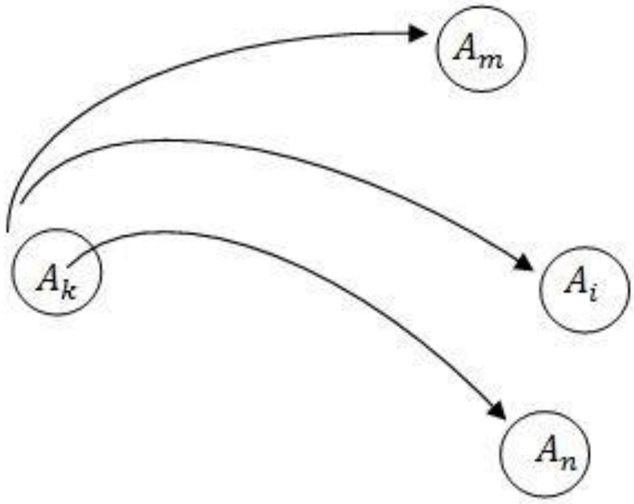

Figure 3.3: the negative outranking ow (Entering ows)

by the other alternatives. Based on these outranking ows, the PROMETHEE I method can provide a partial preorder of the alternatives, whiles PROMETHEE II method can give the complete preorder by using a net ow, though it loses much information of preference relations. Leaving (or positive) ow for A_k alternative,

$$\phi^+(A_k) = \frac{1}{n-1}\sum_{a_i \in A} \pi(A_k, A_i) \qquad (3.55)$$

Figure 3.3: Positive outranking ow (Leaving ows) ($\varphi^+(A_k)$) As indicated in the above Figure, the arrows directed at nodes A_i,A_m,A_n from node A_k depict how the alternative A_k outranks all other alternatives. These directed arrows from A_k are called the positive outranking ows (leaving ows) denoted by $\varphi^+(A_k)$ as indicated above. Entering (or negative) ow for A_k alternative,

$$\phi^-(A_k) = \frac{1}{n-1}\sum_{a_i \in A} \pi(A_i, A_k) \qquad (3.56)$$

The negative outranking ow is represented graphically as shown by Figure 3.2: In the gure above, the arrows from nodes A_i,A_m,A_n and so on. directed at node A_k are referred to as the negative outranking (entering) ows and they show how the alternative $A_k$is outranked by the other alternatives.

Step 6: Calculate the net outranking ow for each alternative.

$$\varphi_{A_k} = \varphi^{+}(A_k) - \varphi^{-}(A_k) \quad (3.57)$$

Step 7: At this stage, deduce the ranking of all the considered alternatives depending on the values of $\varphi(A_k)$ in such a way that the higher value of $\varphi(A_k)$, the better is the alternative. However, the best is the one having the highest $\varphi(A_k)$ value. The PROMETHEE method is an interactive multi-criteria decision-making approach designed to handle quantitative as well as qualitative criteria with discrete alternatives. In the method, pair-wise comparison of the alternatives is performed to compute a preference function for each criterion. Based on this preference function, a preference index A_k over A_i is found. This preference index is the numerical value used to assess whether the hypothesis that, alternative A_k is preferred to A_i is rejected or accepted.

Step eight: Computation of Positive (Leaving) and Negative (Entering) Flow values

With reference to the aggregated preference function indicated in Table 4.15, the following analysis can be drawn: The leaving and the entering ows for di erent facility location alternatives are done by calculating;

The positive (leaving) ow measures the average degree to which an action is preferred to the other ones.

The negative (entering) ow measures the average degree to which the other actions are preferred to that action

. The preference ow formula are given by :

Positive Outranking Flow:

$$\Phi^+(A_k) = \frac{1}{n-1} \sum_{A_i \epsilon A}^{n} \Pi(A_k, A_i) \quad (3.58)$$

Negative Outranking Flow:

$$\Phi^-(A_k) = \frac{1}{n-1} \sum_{A_i \epsilon A}^{n} \Pi(A_i, A_k) \quad (3.59)$$

Step nine: The next stage of this work, deals with the calculation of the net outranking ow for each alternative under consideration. However, the net outranking ow is obtained by working out the di erence between the leaving ow(positive) and the entering ow(negative) using the equation below.

$$\Phi(A_k) = \Phi^+(A_k) - \Phi^-(A_k) \quad (3.60)$$

Step ten: Partial Ranking of alternatives

The Partial Ranking of our nite set of alternatives is obtained through the use of equations (3.59) and (3.60).

Step eleven: Complete Ranking for alternatives

In Complete Ranking, we consider pairs of alternatives using their net ows $(\Phi(A_k))$

3.7.3 The TOPSIS methodology.

The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is a multi-criteria decision analysis method, which was originally developed by Hwang and Yoon in 1981 with further developments by Yoon in 1987 and Hwang, Lai and Liu in 1993. TOPSIS is based on the concept that the chosen alternative should have the shortest geometric distance from the positive ideal solution and the longest geometric distance from the negative ideal solution. It is a method of compensatory aggregation that compares a set of alternatives by identifying weights for each criterion, normalizing scores for each criterion and calculating the geometric distance between each alternative and the ideal alternative, which is the best score in each criterion. An assumption of TOPSIS is that the criteria are monotonically increasing or decreasing. Normalization is usually required as the parameters or criteria and often of incongruous dimensions in multi-criteria

problems. Compensatory methods such as TOPSIS allow trade-o s between criteria, where a poor result in one criterion can be negated by a good result in another criterion. This provides a more realistic form of modeling than noncompensatory methods, which include or exclude alternative solutions based on hard cut-o s. TOPSIS methodology.

The TOPSIS process is carried out as follows:

Step 1

Create an evaluation matrix consisting of m alternatives and n criteria, with the intersection of each alternative and criteria given as x_{ij}, we therefore have a

matrix $X_{ij}\, m \times n$

Step 2

The matrix $x_{ijm\times n}$ is then normalized to form the matrix using the normalization method, where p max(v_j) is the maximum possible value of the indicator

V_j,j=1,2,...,n.

Step 3

Calculate the weighted normalized decision matrix

$$T = t_{ij}m \times n = (w_j r_{ij} mxn, j = 1,2,...,m w_j = W_j / \sum_{j=1} W_j, j = 1,2,.....m \tag{3.61}$$

Where so that

$$\sum_{j=1} W_j = 1 \tag{3.62}$$

t and w_j is the original weight given to the indicator v_j, j=1,2,...,n

Step 4

Determine the worst alternative(A_w) and the best alternative(A_b):

$$A_w = max(t_{ij})|i = 1,2,...,m|j \in J-, min(t_{ij})|i = 1,2,...m|j \in J+ \equiv tw_j|j = 1,2,...,n \quad (3.63)$$

$$A_b = min(t_{ij})|i = 1,2,...,m|j \in J-, max(t_{ij})|i = 1,2,...m|j \in J+ \equiv tw_j|j = 1,2,...,n \quad (3.64)$$

Such that;

$$J+ = j = 1,2,..,n, and \quad (3.65)$$

|j associated with the criteria having a positive impact

$$J- = j = 1,2,..,n \quad (3.66)$$

|j associated with the criteria having a negative impact,

Step 5

Calculate the L2-distance between the target alternative i and the worst condition A_w.

$$d_{iw} = \sqrt{\sum_{j=1} (t_{ij} - t_{wj})^2} \quad (3.67)$$

i=1,2,...,m and the distance between the alternative I and the best alternative A_b

$$d_{ib} = \sqrt{\sum_{j=1} (t_{ij} - t_{bj})^2} \quad (3.68)$$

i=1,2,...,m and the distance between the alternative I and the best condition Ab Where diw and dib are L2-norm distances from the target alternative i to the worst and best conditions, respectively.

Step 6

Calculate the similarity to the worst condition:

$$Siw = \frac{dib}{diw + dib}, 0 \leq Siw \leq 1, i = 1, 2 \ldots, m \quad (3.69)$$

S_{iw} = 1, if and only if the alternative solution has the worst condition and

Siw = 0, if and only if the alternative solution has the best condition.

Step 7

Rank the alternatives according to S_{iw} (i=1,2,...,m).

3.7.4 Normalization.

Two methods of normalization that have been used to deal with incongruous criteria dimensions are linear normalization and vector normalization. Linear normalization can be calculated as in Step 2 of the TOPSIS process above. Vector normalization was incorporated with the original development of the TOPSIS method and is calculated using the following formula:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1,j=1} {x_{ij}}^2}} n = 1, 2, \ldots n \quad (3.70)$$

Such that,

$$A_w = \mathrm{h} maxt_{ij} | i = 1,2 \ldots mj \in J - \mathrm{i}, \mathrm{h} mint_{ij} | n = 1,2 \ldots m\mathrm{ij} \in J + t_{iw} \equiv t_{wi} | j = 1,2, \ldots m \quad (3.71)$$

$$A_b = < mint_{ij} | i = 1,2 \ldots mj \in J - >, < maxt_{ij} | n = 1,2 \ldots m > j \in J + t_{iw} \equiv t_{wi} | j = 1,2, \ldots m \quad (3.72)$$

Chapter 4

Data Collection,Analysis,Results and Discussion

4.1 Data Collection

The researcher in the process of nding the best location to site the water treatment plant distributed questionnaire to number of 135 people. Out of this number 122 of them returned them. The questionnaire was given to stake holders made up of people living in and around the catchment towns of Obuasi as well as the companies whose operation deals with the use of water. However, the Statistical Department of Obuasi Municipal Assembly was consulted for information on each town. The age range of people who responded was varied from 18 to 60 years old. However, the manager of water and sewage company at Obuasi was also spoken to and his views on the best location to site the water treatment plant was discussed and some suggestions made. The data for the
questionnaire were collected in the area of Obuasi Municipality, seeking the views and suggestion of all the people living in and around Obuasi. Respondents need to judge the relative comparison between criteria and the relative comparison between alternative with respect to criterion in linguistic scales. Each of these judgments is then assigned an integer on a scale. In this thesis, the original de nition of scale given by Professor Thomas Saaty (1980) was adopted. The scale and their relative importance are explained in Table 1.

A water treatment plant is to be located at Obuasi Municipality by Ghana water company, in some selected towns. The following are some selected towns from which we can get the best location of the facility. Five (5) alternatives/towns were identi ed. Alternatives are Kwabenakwa (A_1), Gausu(A_2), Akaporiso(A_3), Tutuka(A_4) and Abompe (A_5). During the evaluation, ve (5) main criteria/factors C_1: proximity to consumers/User, C_2: nearness to market, C_3: community desirability, C_4: Road network, C_5: other facilities) have been selected. Consequently, the best location selection among ve (5) alternatives has been found.

4.1.1 Organization of Data

A thorough search for information on the views of all stake holders who are directly connected to the bene t derived from the existence of the water treatment plant were taken after an interview, in the form of a questionnaire which was handed over to respondents. The decision-makers personally expressed their views concerning the relative importance of the criteria and preferences among pairs of alternatives using pairwise comparison and Saaty Rating Scale as indicated in table 4.1 was used ranging from 1 to 9. If however, one criterion is preferred less than the comparison criterion, the reciprocal of the preference score is assigned as shown in table 2. The matrix components on the diagonal of this matrix take the value 1, since they are equally important. The underlining factor, but very reasonable assumption is that if C_1 is moderately important than C_3 and is rated at 3, then C_3 must be extremely less important than C_1 and is valued at 1/3.

Table 4.1: Rating Scale developed by saaty(1980)

(Scale)	Relative importance of the element	Explanation
1	equally important	i and j are equally important
2	-	-
3	Moderately important	i is moderately more important than j
4	-	-
5	Strongly important	i is more strongly important than j
6	-	-
7	Very strongly important	i is Very strongly more important than j
8	-	-
9	Extremely important	i is Extremely more important than j
2,4,6,8	Intermediate values	used when a compromise is needed

4.1.2 Questionnaire results

A well designed questionnaire was administered to 135 respondents, out of which 122 were returned. The response given has been summarized in the pair wise comparison matrices from table 4.2-4.7. A sample of the questionnaire which was used is shown in Appendix B.

4.1.3 Constructing the pairwise comparison matrix

After the questionnaires were giving out and collected from various respondents, it was realized that, decision-makers with varied ideas, determined relative values for the criteria and each alternative using Saaty (1980) rating scale of table 4.1 The facts gathered from the questionnaire of the criteria indicated that C_1 in

the rst row and C_1 in the rst column are equally important and have been assigned a value 1; C_1 in the rst row is strongly important than C_2 and the value assigned is 5; C_1 in the rst row is slightly important than C_3 in the rst column, and the value assigned is 2; C_1 in the rst row and C_4 in the rst column are moderately important and assigned 3; C_1 in the rst row and C_5 in the rst column are equally important, value assigned is 1 ; C_2 in the second row and C_2 in the column are equally important, value assigned is 1 and the rest follows in similar trend. However, C_2 in second row is slightly less important than C_1 in the rst column; C_3 in the third row is strongly less important than C_1, therefore, a reciprocal value is assigned to them. Mathematically, it can be expressed as $a_{11} = (C_1,C_1) = 1; a_{12} = (C_1,C_2) = 5; a_13 = (C_1,C_3) = 2; a_{14} = (C_1,C_4) =$

$3; a_{15} = (C_1,C_5) = 1; a_{31} = (C_3,C_1) = 1/2$.

The relative judgments o ered by various stake holders is exhibited by the Pairwise comparison matrix for criteria of the above is indicated in Table 4.2. Likewise, other alternatives have been giving similar explanation and this is exhibited in Table 4.3 4.7.

Table 4.2: Pairwise comparison matrix for criteria taking into consideration, the objectives

	C_1	C_2	C_3	C_4	C_5
C_1	1	5	2	3	1
C_2	1/5	1	3	2	3
C_3	1/2	1/3	1	1/4	2
C_4	1/3	1/2	4	1	4
C_5	1	1/3	1/2	1/4	1

Table 4.3: Pairwise comparison matrix for Alternatives taking C_1 into consideration

	A_1	A_2	A_3	A_4	A_5
A_1	1	0.2	0.5	0.333	0.143

A_2	5	1	1	0.333	0.2
A_3	2	1	1	0.5	0.2
A_4	3	3	2	1	0.333
A_5	7	5	5	3	1

Table 4.4: Pairwise comparison matrix for alternatives taking C_2 into consideration

	A_1	A_2	A_3	A_4	A_5
A_1	1	0.431	0.5	0.25	0.2
A_2	7	1	0.333	0.143	0.25
A_3	2	3	1	0.333	0.5
A_4	4	7	3	1	0.25
A_5	5	4	2	4	1

Table 4.5: Pairwise comparison matrix for alternative taking C_3 into consideration

	A_1	A_2	A_3	A_4	A_5
A_1	1	5	3	2	9
A_2	0.2	1	3	7	3
A_3	0.333	0.333	1	5	2
A_4	0.5	0.143	0.143	1	1
A_5	0.111	0.333	1	1	1

Table 4.6: Pairwise comparison matrix for Alternative taking C4 into consideration

	A_1	A_2	A_3	A_4	A_5
A_1	1	2	2	5	7
A_2	0.5	1	1	3	7
A_3	0.5	1	1	1	5
A_4	0.2	0.333	1	1	3
A_5	0.143	0.143	0.2	0.333	1

Table 4.7: Pairwise comparison matrix for Alternative taking C_5 into consideration

	A_1	A_2	A_3	A_4	A_5
A_1	1	0.333	0.25	0.2	0.111
A_2	3	1	0.5	0.2	0.143
A_3	4	2	1	0.333	0.2
A_4	5	5	3	1	0.5
A_5	9	7	5	2	1

4.2 Data Analysis

In organizing the data for analysis, the public and stakeholders including the management of water and Sewage Company of Ghana and other users of water, which include mainly pure water manufacturers in Obuasi, were consulted for their views on the factors that a ect facility location. After a careful survey,

the analysis was done by the use of AHP , PROMETHEE Method II and the TOPSIS methodology.

4.2.1 Computation of Analytic Hierarchy Process (AHP)

In Calculation of Analytic Hierarchy Process, a number of computations has to be done, in which the following steps outline clearly:

Step one: Weight calculation for each level

The pair wise comparison matrices of Table 4.2 4.7 was used in weight calculation. To begin with, the rst step of the calculation dealt with the summation of the values of each row in the comparison matrix. The sums of the rows are then further added to give the total sum. We now nd the quotient of the total sum and row sum. This is done consecutively for other matrices as indicated in Appendix 1, Table 4.2. The formula below shows how the weight

calculation was done and the weight for criteria and each alternative are indicated in Table 4.8 and 4.9 respectively:

Weight= $\frac{rowsum}{Totalsum}$

Table 4.8: Weight (W) associated with the criteria matrix

Criteria	C_1	C_2	C_3	C_4	C_5
Weight	0.1792	0.1520	0.1302	0.1710	0.1729

Step Two: Forming the Matrix of alternative against Criteria

Table 4.9: Weight (W) for each alternative against the criteria

		Criteria			
Alternatives	C_1	C_2	C_3	C_4	C_5
A_1	0.179191	0.152004	0.130233	0.171026	0.172871
A_2	0.680332	0.633769	0.092465	0.125755	0.441918
A_3	0.387039	0.49628	0.056434	0.085513	0.687428

A_4	0.76856	1.107606	0.01814	0.055667	1.323146
A_5	1.729322	1.162079	0.022429	0.0183	2.190035

Step three: Calculation of the Eigenvalues The maximum eigenvalues λ_{max},were calculated, using the power method.The computation for the λ_{max} of the criteria and the alternative matrices are indicated in appendix 1. However,the results are clearly indicated in Table 4.10.

Table 4.10: Computed eigenvalues for main criteria and alternatives

	C	A_1	A_2	A_3	A_4	A_5
λ_{max}	6.200676	5.24723	6.039941	6.074213	5.150471	5.155474

Step four: Calculating the Consistency Index and Consistency Ratio

The consistency index and ratio of Table 4.2 4.7 were calculated using the formulas below and it is summarized in Table 4.11.This formula is given by

Consistency Index(C.I.) = $\frac{\lambda_{max} - n}{n-1}$

Such that λ_{max} represent the maximum eigenvalue and n=5 denote the size of the pairwise comparison matrix. Taking λ_{max} = 6.200676 obtained after the iteration for the criteria matrix. We have the consistency index as;

C.I= $\frac{200676-5}{5-1}$ 6.

C.I=0.300169

However, as indicated in table 3.2, Saaty (1980) has calculated Random Index (R.I.) corresponding to the size of square matrix. In our case, the Consistency Ratio (C.R.) is calculated by nding the quotient of the Consistency Index and Random Index for the corresponding size of the matrix. Since n=5 representing the 5x5 square pairwise matrix , the R.I = 1.12 and the computation is indicated in the equation below.

$$ConsistencyRatio(C.R) = \frac{C.I}{R.I} = \frac{0.300169}{1.12} = 0.268008$$

The corresponding Consistency Index(C.I.) and Consistency Ratio(C.R.)for criteria and all the alternatives are indicated in Table 4.11 Table 4.10: A table showing Consistency Index and Consistency Ratio for criteria and alternatives

The Consistency Ratios are acceptable, since all the values below are less than

Table 4.11: A table showing Consistency Index and Consistency Ratio for criteria and alternatives.

	C	A_1	A_2	A_3	A_4	A_5
C.I	0.080312	0.061808	0.07216	0.09749	0.037618	0.038869
C.R	0.71707	0.055185	0.064429	0.087045	0.033587	0.034704

10 (0.1).

4.2.2 Computation by PROMETHEE II method

The PROMETHEE II method is applicable at this stage and the steps are outlined as follows:

Step ve: At this stage, we normalize the decision matrix by applying the following equation The decision matrix was obtained by multiplying the weight of the rst criteria (C_1) in Table 4.8 by each alternative in the rst column of Table 4.9, weight of the second criteria (C_2) by each alternative in the second column and several others in that order as indicated in the appendix.

However, the decision matrix of alternatives with respect to the criteria is computed as follows: Entries in decision matrix are x_{ij} and are called performance measure.

$$R_{ij} = \frac{[X_{ij} - minX_{ij}]}{[maxX_{ij} - minX_{ij}]} \quad (4.1)$$

Table 4.12: Decision Matrix

LOCATION	C_1	C_2	C_3	C_4	C_5
A_1	0.179191	0.152004	0.130233	0.171026	0.172871
A_2	0.680332	0.633769	0.092465	0.125755	0.441918
A_3	0.387039	0.49628	0.056434	0.085513	0.687428
A_4	0.76856	1.107606	0.01814	0.055667	1.323146
A_5	1.729322	1.162079	0.022429	0.0183	2.190035

i = 1,2,..,n,j = 1,2,...,m where X_{ij} is the performance measure of i^{th} alternative with respect to j^{th}

criterion.

$$R_{ij} = \frac{[0.179191 - 0.179191]}{[1.729322 - 0.179191]} = 0$$

Calculation for each element is done using equation 4.1 and the normalized values of decision matrix are shown in Table 4.12. Entries are R_{ij} and it is denoted by

$A_{ij} = R_{ij}$

Table 4.13: Normalized Decision Matrix.

LOCATION	C_1	C_2	C_3	C_4	C_5
A_1	0.0000	0.0000	1.0000	1.0000	0.0000
A_2	0.323289	0.47696	0.663065	0.70358	0.133379
A_3	0.134084	0.132396	0.341627	0.440089	0.255089
A_4	0.380206	0.94607	0.0000	0.038263	0.570244
A_5	1.0000	1.0000	0.038263	0.0000	1.0000

Step six: Computation of the preference function, $P_{ij}A_k,A_i$ To avoid the de nition of some preferential parameters, such as the preference and indi erence thresholds, the following simpli ed preference function is adopted here taking into consideration Table 4.13:

$$P_{ij}(A_k,A_i) = 0 \tag{4.2}$$

if $A_{kj} \leq A_{ij}$

$$P_{ij}(A_k,A_i) = A_{kj} - A_{ij} \tag{4.3}$$

if$A_{kj} \geq A_{ij}$ where $P_{ij}(A_k,A_i)$ is a number between 0 and 1 which increases if $(A_{kj} - A_{ij})$ is large and equals zero if $A_{kj} \leq A_{ij}$. Now, the preference function is the di erence between the pairs of alternatives, and this is calculated for all the pairs of alternatives, employing equations (4.2) and (4.3), and are given in Table (4.14).

Table 4.14: location Pair

LOCATION PAIR	C_1	C_2	C_3	C_4	C_5
A_1,A_2	0.0000	0.0000	0.336935	0.29642	0.00000
A_1,A_3	0.0000	0.0000	0.658373	0.559911	0.00000
A_1,A_4	0.0000	0.0000	0.00000	0.961737	0.00000
A_1,A_5	0.0000	0.0000	0.961737	0.00000	0.00000
A_2,A_1	0.32328	0.47696	0.00000	0.00000	0.133379
A_2,A_3	0.32328	0.47696	0.00000	0.00000	0.133379
A_2,A_4	0.0000	0.0000	0.663065	0.665317	0.00000
A_2,A_5	0.0000	0.0000	0.624802	0.70358	0.00000

A_3,A_1	0.134084	0.132396	0.00000	0.00000	0.255089
A_3,A_2	0.0000	0.0000	0.00000	0.00000	0.12171
A_3,A_4	0.0000	0.341627	0.341627	0.401826	0.00000
A_3,A_5	0.0000	0.303364	0.303364	0.440089	0.00000
A_4,A_1	0.380206	0.94607	0.00000	0.00000	0.570244
A_4,A_2	0.056917	0.0000	0.00000	0.00000	0.436865
A_4,A_3	0.246122	0.0000	0.00000	0.00000	0.315155
A_4,A_5	0.0000	0.0000	0.00000	0.038263	0.00000
A_5,A_1	1.0000	0.0000	0.00000	0.00000	1.00000
A_5,A_2	0.676711	0.0000	0.00000	0.00000	0.866621
A_5,A_3	0.865916	0.0000	0.00000	0.00000	0.744911
A_5,A_4	0.619794	0.038263	0.038263	0.00000	0.429756

Step seven: Aggregated Preference Function The next stage, is the aggregated preference function, which is derived by nding the sum of the entire individual preference index and the results are summarized in the table below. Table 4.14 exhibits the aggregated preference function values for all the paired of alternatives,as calculated using equation(4.4)

$$\Pi(A_k, A_i) = \frac{[\sum_{j=1}^{m} W_j P_j(A_k, A_i)]}{\sum_{j=1}^{m} W_j} \quad (4.4)$$

Step eight: Computation of Positive (Leaving) and Negative (Entering) Flow values

With reference to the aggregated preference function indicated in Table 4.15, the following analysis can be drawn: The leaving and the entering ows for di erent facility location alternatives are done by calculating;

Table 4.15: Aggregated preference function

LOCATION	A_1	A_2	A_3	A_4	A_5
A_1		0.014155	0.027229	0.021495	0.021495
A_2	0.023286		0.027903	0.033133	0.0331902
A_3	0.01166	0.002722		0.02427	0.023417
A_4	0.042425	0.011046	0.012555		0.000855
A_5	0.037899	0.029246	0.030524	0.021338	

The positive (leaving) ow measures the average degree to which an action is preferred to the other ones.

The negative (entering) ow measures the average degree to which the other actions are preferred to that action.

The preference ow formula are given by Positive Outranking Flow:

$$\Phi^{+}(A_k) = \frac{1}{n-1} \sum_{A_i \epsilon A}^{n} \Pi(A_k, A_i) \tag{4.5}$$

Negative Outranking Flow:

$$\Phi^{-}(A_k) = \frac{1}{n-1} \sum_{A_i \epsilon A}^{n} \Pi(A_i, A_k) \tag{4.6}$$

The values of the positive and negative ows are shown in Table 4.16

Table 4.16: Leaving and entering ows for di erent locations.

LOCATION	Leaving ow($\Phi^{+}(A_k)$)	Entering ow($\Phi^{-}(A_k)$)	Di erence
A_1	0.0211088	0.0288175	-0.0077087
A_2	0.0293781	0.0142923	0.0150858
A_3	0.0155173	0.02455275	-0.00903545
A_4	0.0167203	0.0250590	-0.0083387
A_5	0.0297622	0.0197393	0.0100229

Step nine: The next stage of this work, deals with the calculation of the net outranking ow for each alternative under consideration. However, the net outranking ow is obtained by working out the di erence between the leaving

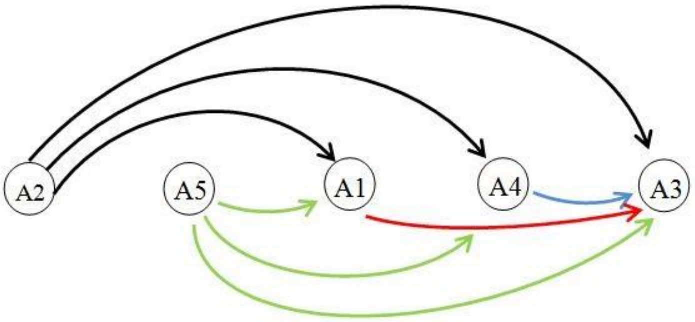

Figure 4.1: A Graph exhibiting partial ranking of alternatives ow(positive) and the entering ow(negative) using the equation below.

$$\Phi(A_k) = \Phi^+(A_k) - \Phi^-(A_k) \quad (4.7)$$

The net outranking ow values for di erent alternative location and their relative rankings are indicated on the table 4.17. As clearly indicated on the table, it is

Table 4.17: Leaving and entering ows for di erent locations

LOCATION	Net outranking ow	Rank
A_2	0.0150858	1
A_5	0.0100229	2
A_1	-0.0077087	3
A_4	-0.0083387	4
A_3	-0.0090355	5

observed that $A_2 > A_5 > A_1 > A_4 > A_3$ where > means alternative better than . Therefore, A_2 is the best alternative to be chosen for the location of the water treatment plant at the Obuasi municipality.

Step ten: Partial Ranking of alternatives

The Partial Ranking of our nite set of alternatives is obtained through the use of equations (4.5) and (4.6). With reference to Figure 4.1 above, it is clearly indicated that there is no connection between A_2 and A_5, A_1 and A_4. Implying that, the two alternatives are incomparable. For this reason, we apply the complete ranking method.

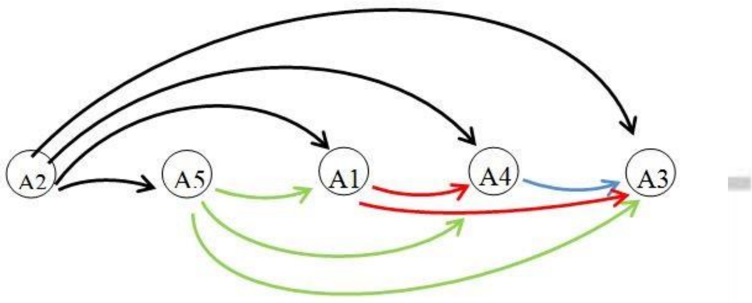

Figure 4.2: A Graph exhibiting complete ranking of alternatives

Step eleven: Complete Ranking for alternatives

In Complete Ranking, we consider pairs of alternatives using their net ows ($\Phi(A_k)$). This is achieved using equation (4.7). The net ows for the ve (5) alternatives are displayed in Table 4.17. With reference to the above, Table 4.17, the ranking is done taking into consideration the di erence between leaving ow and entering ow such that the best alternative is obviously the one with the largest numerical value. In view of that, the best location for the water treatment plant is evidently Gausu, which was assignedA_2, implying the second alternative among the selected locations for the facility.

As clearly indicated on the table, it is observed that $A_2 > A_5 > A_1 > A_4 > A_3$ where

\> means alternative better than . Therefore, A_2 is the best alternative to be chosen for the location of the water treatment plant at the Obuasi municipality.

4.3 The TOPSIS Methodology

Creating an evaluation matrix consisting of ve(5) alternatives and ve(5) criteria, with the intersection of each alternative and criteria. Kwabenakwa(A_1), Gausu(A_2), Akaporiso(A_3), Tutuka (A_4) and Abompe(A_5)

Nearness to the market (C_1),Nearness to source of power (C_2),Community desirable (C_3),Road network (C_4) and other facility (C_5)

Step 1

Table 4.18: Decision Matrix

LOCATION	C_1	C_2	C_3	C_4	C_5
A_1	0.179191	0.152004	0.130233	0.171026	0.172871
A_2	0.680332	0.633769	0.092465	0.125755	0.441918
A_3	0.387039	0.49628	0.056434	0.085513	0.687428
A_4	0.76856	1.107606	0.01814	0.055667	1.323146
A_5	1.729322	1.162079	0.022429	0.0183	2.190035

Step 2: Normalization of the decision matrix

The matrix $\{x_{ij}\}_{m\times n}$ is then normalized to form the matrix using the normalization method where p max(vj) is the maximum possible value of the indicator V_j ,j=1,2,...,n .

Table 4.19: Normalized Decision Matrix.

LOCATION	C_1	C_2	C_3	C_4	C_5
A_1	0.0000	0.0000	1.0000	1.0000	0.0000
A_2	0.323289	0.47696	0.663065	0.70358	0.133379
A_3	0.134084	0.132396	0.341627	0.440089	0.255089
A_4	0.380206	0.94607	0.0000	0.038263	0.570244
A_5	1.0000	1.0000	0.038263	0.0000	1.0000

Step 3:The weighted normalized Decision Matrix.

Step 4:Determining the worst alternative(A_w) and the best alternative(A_b) :

$A_w = \{[max(t_{ij}|(i = 1,2,...,5)|j\epsilon J], [min(t_{ij}|i = 1,2,...5)|j\epsilon J+]\} \equiv \{t_{wj}|j = 1,2,...,5\}$

$A_b = \{[min(t_{ij}|i = 1,2,...,5)|j\epsilon\}$ Such that, $J+ = \{j = 1,2,..,5|j\}$ associated with the criteria having a positive impact, and $J- = \{j = 1,2,..,5|j\}$ associated with the criteria having a negative impact, and

Step 5: Calculating the L2-distance between the target alternative i and the worst condition A_w.

and the distance between the alternative I and the best condition A_b Where d_{iw} and d_{ib} are L2-norm distances from the target alternative i to the worst and best

LOCATION	AW(Worst Alternative)	AB(Best Alternative)	Target Alternative
A1	0.489487	0.544194	0.000000
A2	0.324561	0.391351	0.068095
A3	0.201696	0.489487	0.072965
A4	0.370220	0.458309	0.000000
A5	0.544194	0.510539	0.000000

Figure 4.3: Weighted normalized decision Matrix

$$d_{iw}=\sqrt{\sum_{j=1}^{5}(t_{ij}-t_{wj})^2}=0.86899 \quad ,i=1,2,\ldots,5$$

and the distance between the target alternative I and the best alternative A_b

$$d_{ib}=\sqrt{\sum_{j=1}^{5}(t_{ij}-t_{bj})^2}=1.022168 \quad ,i=1,2,\ldots,5$$

Figure 4.4: A table of alternative against criteria

conditions, respectively.

Step 6: Calculating the similarity to the worst condition:

$$S_{iw}=\frac{d_{ib}}{(d_{iw}+d_{ib})}0\leq S_{iw}\leq 1, i=1,2\ldots,5 \tag{4.8}$$

S_{iw} = 1 if and only if the alternative solution has the worst condition;

S_{iw} = 0 if and only if the alternative solution has the best condition

S_{iw} = (1.022168)/(0.86899 + 1.022168) = 0.54049 since 0.5 is approximately 1 the alternative solution has the worst condition

Step 7

Ranking of the alternatives according to Siw (i=1,2,...,5).

LOCATION	Siw	RANK
A1	0.546646	3
A2	0.708187	1
A3	0.4840450	5
A4	0.5264620	4
A5	0.553179	2

Figure 4.5: Ranking of the alternatives according to S_{iw}

4.3.1 Normalization

Two methods of normalization that have been used to deal with incongruous criteria dimensions are linear normalization and vector normalization. Linear normalization was calculated as in Step 2 of the TOPSIS process above. Vector normalization was incorporated with the original development of the TOPSIS method and is calculated using the following formula:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{n} x^2}}, 1,2,\ldots,5$$

LOCATION	Xij	$R_{ij} = \frac{x_{ij}}{\sqrt{\sum_{j=1}^{5} x^2}}$	RANKING OF ALTERNATIVES
A1	0.546646	0.429774	3
A2	0.708187	0.557113	1
A3	0.4840450	0.380557	5
A4	0.5264620	0.413906	4
A5	0.553179	0.434939	2

Figure 4.6: A table showing the ranking of Alternatives

Figure 4.7: Ranking of location by S_{iw}

$$A_w \equiv \{t_{wi} | j = 1,2\ldots5\} \qquad (4.9)$$

J+, j=1,2,...,n ,j+ associated with the criteria having a positive impact.

$$A_b \equiv \{t_{bi} | j = 1,2,\ldots5\} \qquad (4.10)$$

J-, j=1,2,...,n ,j- associated with the criteria having a negative impact.

4.4 Result

The location which has the largest numerical value, suggest the best location by the AHP/PROMETHEE II ranking method. In accordance with the results generated Gausu has the highest net outranking ow of 0.0150858 in comparison with the rest of the locations. The AHP/PROMETHEE II method ranking for the facility location is: (A_2) Gausu (score: 0.0150858), (A_5) Abompe(score: 0.0100229), (A_1) Kwabenakwa (score: -0.0077087), (A_4) Tutuka (score: -

0.0083387), and the last rank is (A_3) Akaporiso (score: -0.00903545). However the results obtained from the TOPSIS methodology exhibited that the highest ranked alternative with the best condition was A_2 which is again Gausu.

4.5 Discussion

With reference to the above results obtained, incomparability existed when partial ranking was used to rank all alternatives from best to worst. Hence complete ranking was used, as a result of that there was no incomparability. A_2 (Gausu) is the best alternative to be selected for the facility location. This is as a result of the fact that the alternative with the highest numerical value also has the highest net outranking ow of 0.0150858 in comparison with the rest of the locations.

The TOPOSIS methodology equally showed that the best location for the water treatment plant in the Obuasi municipality was Gausu, which was ranked highest among all the other locations.

Chapter 5

Conclusion and Recomendation

This Chapter is the last but not the least, here it focuses on the highlights of the conclusions and recommendations that are drawn from the methods or procedural steps adopted in the presentation of facts gathered and exhibited in this thesis.

5.1 Conclusion

With reference to the Facility Location Selection using the AHP/PROMETHEE II ranking Method and the TOPSIS, the following conclusions can be drawn:

AHP/PROMETHEE II ranking methodology and TOPSIS has been adopted and executed successfully to provide consistent evaluation (weighting and ranking) of location alternatives.

AHP/PROMETHEE II ranking method and TOPSIS were employed to select the best alternative or central point for the facility (Water treatment plant) to be located.

The AHP/PROMETHEE II ranking method and TOPSIS can also be used to determine the factors that in uence facility location for any given plant location in the municipality.

5.2 Recomendations

With reference to the research work the following recommendations are outlined below:

It is recommended that this AHP/PROMETHEE II ranking method and TOPSIS should be used by the Obuasi Municipal Assembly and Ghana water and sewage company in Obuasi to select the best facility location for the water treatment plant.

It is recommended that further studies be made by other researchers using other methods in order to compare results obtained with this work and other similar ones.

It is again recommended that more people are skillfully trained to understand the use of pair wise comparison used in the AHP/PROMETHEE II ranking method which makes implementation of this method signi cantly simple.

It is recommended that this approach can signi cantly help in making any multi criteria decision in any industrial eld.

Finally, it is expected that similar plant location should be cited using the AHP/PROMETHEE II ranking method and con rmed with TOPSIS.

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Appendix A

Figure 5.1: Pairwise comparison between alternatives with respect to C_1

				FIRST ITERATION							
	A1	A2	A3	A4	A5	TOTAL	WEIGHT	AW			
A1	1	0.2	0.5	0.333	0.143	2.176	0.04863439	0.271411403		5.580648	
A2	5	1	1	0.333	0.2	7.533	0.16836529	0.679917952		4.03835	
A3	2	1	1	0.5	0.2	4.7	0.10504671	0.568850297		5.415213	
A4	3	3	2	1	0.333	9.333	0.20859595	1.225984534		5.877317	
A5	7	5	5	3	1	21	0.46935765	2.802646283		5.971238	
						44.742		5.548810469		26.88277	5.376
									1.500851	5.529802	
									3.574607	5.25741	
									2.965113	5.212466	
									6.150954	5.017155	
									14.62432	5.21804	
										26.23487	5.246

Figure 5.2: Pairwise comparison between alternatives with respect to C_2 Figure 5.3: Pairwise comparison between alternatives with respect to C_3

				SECOND ITERATION							
	A1	A2	A3	A4	A5	TOTAL	WEIGHT	AW			
A1	1	0.333	0.5	0.25	0.2	2.28333333	0.05695187	0.325191017		5.709927	
A2	3	1	0.333	0.143	0.25	4.726	0.1178779	0.481816282		4.087418	
A3	2	3	1	0.333	0.5	6.833	0.17043159	0.922643149		5.413569	
A4	4	2	3	1	0.25	10.25	0.25565985	1.330287586		5.20335	
A5	5	4	2	4	1	16	0.39907879	2.518852316		6.311667	
						40.0923333		5.578790351		26.72593	5.34
									1.78346	5.484347	
									2.584574	0.632324	
									4.720886	5.116698	
									6.992327	5.256252	
									13.23851	5.25577	
										21.74539	4.34

	A1	A2	A3	A4	A5	TOTAL	WEIGHT	AW			
					THIRD ITERATION						
A1	1	2	4	4	4	15	0.3355526	2.34460719		6.987302	
A2	0.5	1	3	7	3	14.5	0.32436751	1.694540613		5.224138	
A3	0.250	0.333	1	5	2	8.583	0.19201065	0.81677763		4.253814	
A4	0.25	0.143	0.143	1	0.5	2.03571429	0.04553928	0.254460719		5.587719	
A5	0.250	0.333	1	2.000	1	4.583	0.10252996	0.577629827		5.633766	
						44.702381		5.688015979		27.68674	5.53
									12.32916	5.258519	
									8.831292	5.211614	
									4.39534	5.381317	
									1.488187	5.848397	
									3.054328	5.28769	
										26.98754	5.39

Figure 5.4: Pairwise comparison between alternatives with respect to C_4

	A1	A2	A3	A4	A5	TOTAL	WEIGHT	AW			
					FOURTH ITERATION						
A1	1	2	2	5	7	17	0.3748425	2.191726165		5.847059	
A2	0.5	1	1	3	7	12.5	0.27561949	1.297249055		4.706667	
A3	0.5	1	1	1	5	8.5	0.18742125	0.97301554		5.191597	
A4	0.2	0.333	1	1	3	5.53333333	0.12200756	0.596598068		4.889845	
A5	0.143	0.143	0.200	0.333	1	1.819	0.0401092	0.211185776		5.265271	
						45.352381		5.269774605		25.90044	5.18
									11.19355	5.107183	
									6.634222	5.11407	
									5.018655	5.157836	
									3.073933	5.152435	
									1.10308	5.223268	
										25.75479	5.15

	A1	A2	A3	A4	A5	TOTAL	WEIGHT	AW			
					FIFTH ITERATION						
A1	1	0.333	0.25	0.2	0.111	1.894	0.0358996	0.207667203		5.784667	
A2	3	1	0.5	0.2	0.143	4.843	0.09177182	0.390774691		4.258112	
A3	4	2	1	0.333	0.2	7.533	0.14275616	0.652449204		4.570375	
A4	5	5	3	1	0.5	14.500	0.27477403	1.568798785		5.709414	
A5	9	7	5	2	1	24.000	0.45479839	2.683626355		5.900694	
						52.771		5.503316238		26.22326	5.24
									1.112978	5.359432	
									2.037136	5.21307	
									3.324326	5.095149	
									7.860169	5.010311	
									13.6879	5.100523	
										25.77848	5.15

Figure 5.5: Pairwise comparison between alternatives with respect to C_5 Figure 5.6: Pairwise comparison among criteria

SIXTH ITERATION

	Criteria										
Alternative	C1	C2	C3	C4	C5	TOTAL	WEIGHT	AW			
A1	0.179191	0.152004	0.130233	0.171026	0.172871	0.805325	0.06248864	0.163934343		2.623426	
A2	0.680332	0.633769	0.092465	0.125755	0.441918	1.974239	0.15318972	0.359467468		2.346551	
A3	0.387039	0.49628	0.056434	0.085513	0.687428	1.712694	0.13289532	0.402647421		3.029809	
A4	0.76856	1.107606	0.01814	0.055667	1.323146	3.273119	0.25397543	0.760134451		2.992945	
A5	1.729322	1.162079	0.022429	0.0183	2.190035	5.122165	0.39745089	1.164141358		2.929019	
						12.887542		2.85032504		13.92175	2.7
									0.467703	2.85299	
									0.986626	2.744687	
									1.129833	2.806011	
									2.114089	2.781204	
	[X_i-min(X_i)]/[max(X_i)-min(X_i)]								3.273677	2.812095	

LOCATION	LEAVING FLOW	ENTERING FLOW	DIFFERENCE
A1	0.021094	0.028817	-0.007723
A2	0.029378	0.0142922	0.0150858
A3	0.015517	0.0245528	-0.0090358
A4	0.0167203	0.0025059	0.0142144
A5	0.0297518	0.0197393	0.0100125

Figure 5.7: Di erences between leaving and Entering ow

Appendix B

APPENDIX B

Questionnaire used to tap decision makers opinion about the facility location selection in the Obuasi Municipality is shown below.

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, KUMASI

INSTITUTE OF DISTANCE

LEARNING (IDL)

QUESTIONNAIRE FOR PEOPLE IN THE OBUASI MUNICIPALITY

This questionnaire seeks to gather data on the facility location selection in the Obuasi Municipality for analysis and recommendations of the best location to locate a water treatment plant. Any information given will be treated as con dential. Thank you for being a part of this study. Note: You are kindly requested to tick in the space or on the number of options provided. Section 1: Characteristics of

Respondents 1. Sex

(i) Male ( )

(ii) Female ( )

2. Age:..

3. The Format of Scale: To express the relationship between two criteria with respect to objectives as well as alternatives with respect to criteria, the following format the Saaty (1980) Rating Scale 9-point scale as shown below, is proposed to score the items for respondents. Note: 1 Equally important; 3 Moderately important; 5 Strongly important; 7 Very strongly important; 9 Extremely important 2,4,6,8

Intermediate values between the two adjacent judgments Tick √ the corresponding score in the symbol During the evaluation, ve (5) main criteria/factors (C_1: proximity to customers/User, C_2: nearness to market, C_3: community desirability, C_4:Road network , C_5: other facilities) have been selected. Alternatives are Kwabenakwa(A_1),

Gausu(A_2), Akaporiso(A_3), Tutuka(A_4) and Abompe (A_5)

Figure 5.8: Compare two criteria with respect to objectives

Compare two criteria with respect to objectives

C	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C2
C	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C3
C1	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C4
C	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C5
C	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C1
C	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C3
C2	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C4
C2	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C5
C3	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C1
C3	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C2
C3	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C4
C3	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C5
C4	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C1
C4	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C2
C4	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C3
C4	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C5
C5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C1
C5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C2
C5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C3
C5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	C4

Suggestions:…………………………………………………