An Object Oriented System for Optimal Location of Landfills for Nigerian Municipals

By

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PhD/CS/05/0207

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AN OBJECT ORIENTED SYSTEM FOR THE LOCATION OF LANDFILLS WITH MINIMUM POLLUTION FOR NIGERIAN MUNICIPALS

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A THESIS SUBMITTED TO THE DEPARTMENT OF COMPUTER SCIENCE, SCHOOL OF PURE AND APPLIED SCIENCES, MODIBBO ADAMA UNIVERSITY OF TECHNOLOGY, YOLA, NIGERIA, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF DOCTOR OF PHILOSOPHY IN COMPUTER SCIENCE.

April, 2012

DECLARATION

I hereby declare that this thesis was written by me and it is a record of my own research work. It has not been presented before in any previous application for a higher degree. All references cited have been duly acknowledged.

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AGAJI, Iorshase Date

DEDICATION

This thesis is dedicated to God Almighty for His mercy, love and kindness.

APPROVAL PAGE

This thesis entitled "AN OBJECT ORIENTED SYSTEM FOR OPTIMAL LOCATION OF LANDFILLS FOR NIGERIAN MUNICIPALS" meets the regulations governing the award of the Degree of Doctor of Philosophy (PhD) of the Modibbo Adama University of Technology, Yola and is approved for its contribution to knowledge and literary presentation

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ABSTRACT

In this work a system that selects landfills leading to minimum pollution is designed and implemented. The system is broken into four phases. The first phase makes use of the hydrological and environmental factors such as degree of infiltration, degree of elevation and depth of water table. The sites that passed the first phase are forwarded to the second phase. The second phase makes use of factors such as distance from settlements, proximity to road networks, proximity to sensitive sites and proximity to arable land. Again sites that passed the test are forwarded to the next phase. The third phase uses a set of miscellaneous factors such as economic impact, environmental impact and public acceptability, where the sites selected are the ones that pass the test for this phase. The fourth phase provides the location of the selected sites in terms of longitude and latitude. The system was implemented using VB 6.0 and tested on twenty (20) sites. The sites were identified as sites A, B, …, T. Sites B, D, I and S were easily selected. The selection of these sites led to minimum pollution.

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CHAPTER ONE: INTRODUCTION

1.1 Background of the Study

Solid waste management is a major problem for emerging municipals in developing countries. The term solid waste means materials such as household garbage, food wastes, yard wastes and construction or demolition wastes. It also includes discarded items like household appliances, furniture, computer parts, car parts, or abandoned junk vehicles.

The increase in the amount of solid waste in Nigeria can be attributed primarily to the growth of human population as well as increased economic activities in both urban and rural areas. A strong characteristic of this type of waste is that it cannot be avoided as most human activities lead to its generation. Subsequently the burden for management of solid waste can be borne by all and sundry. This also dictates that there should be careful planning and adequate deployment of resources in the management of solid waste.

Agunwamba(2001) defines solid waste management as the control of solid waste generation, storage, collection, transfer and transport, processing and disposal activities based on engineering principles at minimum environmental impacts and costs. Solid waste is generated from homes, industries and public institutions like schools and hospitals and the volume of solid waste depends primarily on the nature of economic activities carried out at such places.

Solid waste is removed from waste bins to landfills directly or moved to transfer stations where it is subsequently moved to landfills, recycling or incinerating centres. It involves the deployment of a fleet of garbage trucks and other transportation issues.

Solid waste can also be processed by changing its physical and sometimes chemical state to produce new materials or generate energy. In Nigeria, in most cases, solid waste is dumped in a landfill or burnt up in incinerators.

The essence of incinerating solid waste is to destroy all harmful organisms associated with such wastes as well as the reduction of the amount of solid waste eventually taken to landfills. It can also be used to generate energy and since incineration involves the burning of solid waste at high temperature, extreme care must be taken to avoid gaseous pollution of the environment.

Landfills provide an avenue for an open dump of solid waste. Landfills are locations that are difficult to come by and as such every measure must be put in place to elongate their life span. Such measures include the compression and reduction of solid waste before landfilling. Also after landfilling, compacting vehicles can be made to run over the waste a number of times in order to reduce the volume of the waste.

In Nigeria, there have been various efforts to solve the problem of solid waste management. The creation of Federal Ministry of Environment and Ministries of Environment by some State Governments as well as other waste management agencies is seen as a step in that direction. The Federal Government policy on solid waste management is reported in Federal Ministry of Environment, Abuja [FMOEA] (2005). This spells out the objectives, strategies and institutional roles as it affects solid waste management. The objectives include:

i To develop policy guidelines for efficient and sustainable solid waste management

ii To promote a healthy environment by ensuring sanitary solid waste management.

iii To optimize labour and equipment in waste management in order to enhance increased productivity.

iv To enhance safe and nuisance free disposal of wastes so as to adequately protect public health system during and after collection, transportation, treatment and final disposal.

The strategies adopted are to

i evolve and promote appropriate technologies for recycling of waste components.

ii promote waste minimization at household and community levels through reduction at source, reuse recycling and resource recovery.

iii ensure efficient monitoring and evaluation of municipal solid waste management practices.

Solid waste is generated by the activities of nearly everybody in a given geographical enclave and as such everybody should be involved in its management. The FMOEA(2005), further provides guidelines for efficient management of solid waste. The guidelines affect all functional aspects of solid waste management from storage to landfilling.

The guidelines recommend the procurement and installation of dustbins and disposable refuse bags for collection and storage of solid waste at household level, mammoth and dinosaur bins at strategic commercial and industrial areas respectively.

A variety of vehicles are recommended for primary refuse collection. These are handcarts, pedal tricycles and animal drawn carts for areas that cannot be accessed by motorized vehicles. All transport vehicles must be covered to prevent dispersal of waste. Sanitary landfill was recommended as the most cost-effective means of solid waste management means. Other means of solid waste management recommended are biological decomposition of organic waste to produce biogas, incineration and recycling.

The institutional guidelines spell out the roles to be played by the Federal, State and Local Governments, Private Sector, Civil Society Organizations as well as the general public. The management of solid waste by the above agencies has been characterized in many cases by lack of planning and has led to losses in terms of finance and man-hours. Agaji and Wajiga (2007) reported that the computer as a tool has not been deployed to help in planning and managing solid waste in Nigeria.

1.2 Solid Waste Management as a Graph Problem

Most of the entities in solid waste management have their roots from graph theory and combinatorial optimization and we briefly examine some of the entities here.

A graph is a 2-tuple G= (V, E) where V= $\{v_1,v_2, \ldots, v_n\}$ is a finite set of vertices and E=$\{(v_i, v_j): v_i, v_j \in V\}$, a finite set of edges where each edge is a two-element multiset from V. The underlying network of roads together with the stop stations (garbage bins) could constitute a graph with roads standing for the edges and stop stations standing for vertices. A graph is connected if every two vertices are joined by an edge otherwise it is disconnected. In order to remove wastes from garbage bins, the bins must be joined by a network of roads. A tripartite graph is a graph with a set of vertices divided into three sets$\{ x_1, x_2, \ldots, x_n\}$,$\{ y_1, y_2, \ldots, y_m\}$ and $\{ z_1, z_2, \ldots, z_l \}$ such that no two vertices within the same set are adjacent. This is especially true as one cannot move waste from a generation node to be dumped in another generation node; neither do we move wastes from one landfill to another landfill.

The movement of the solid waste from originating points to transfer stations and subsequently to either landfills or incineration centres is a general vehicle routing problem (GVRP). The problem is that of finding routes for the fleet of vehicles with minimum cost that obeys the following.

i Each route starts and ends at a depot, a depot in the sense of solid waste management system being the garage where garbage trucks are kept.

ii Each vertex is visited exactly once by one vehicle at a time. A vertex here is a waste bin.

iii The total waste for each route must not exceed the vehicle capacity. This is to ensure two things: a vehicle of smaller capacity is not allocated to a route with larger waste volume and vice versa. This also ensures that wastes found along such routes are removed.

iv The duration of time spent on the route including time wasted on hold ups and service time does not exceed a prescribed time limit.

v Minimize the total cost of routing garbage vehicles; the major daily cost of routing being the cost of fuelling..

GVRP is a difficult problem to solve. The Dijkstra's algorithm is used to estimate and minimize the cost of visiting all vertices in the graph.

Observation about circuits

In a GVRP there are two circuits that are frequently encountered. These are Eulerian circuit which is defined as a tour of the graph using each edge exactly once and a Hamiltonian cycle which is a tour passing through each vertex exactly once.

If a circuit C includes vertex v and we observe that the edges at each vertex are paired into entrance and exit edges and hence C includes an even number of edges incident with v. It follows immediately from this observation that if a connected graph has a Eulerian circuit then the degree of each vertex is even. Townsend (1987) reported a method of constructing Eulerian circuits. With his method we can construct an Eulerian circuit by beginning a trail at any vertex v and continuing the trail as far as possible always taking an unused edge from the last vertex visited.

The process halts because there are only a finite numbers of edges. Also since the degree of every vertex is even there is an exit from every vertex except v and in fact we return to v having constructed a circuit C. If C matches all the edges then we are done. Otherwise since G is connected there is an unused edge incident with some vertex v in V. By the observation on circuits above there is still an even number of unused edges at each vertex and we repeat the process starting at v. In this manner we create a sequence of circuits C, C', C''…. Eventually all edges are used and we hook the circuits together by inserting C^1 into C at v and so on. Consider the graph shown in fig. 1.1

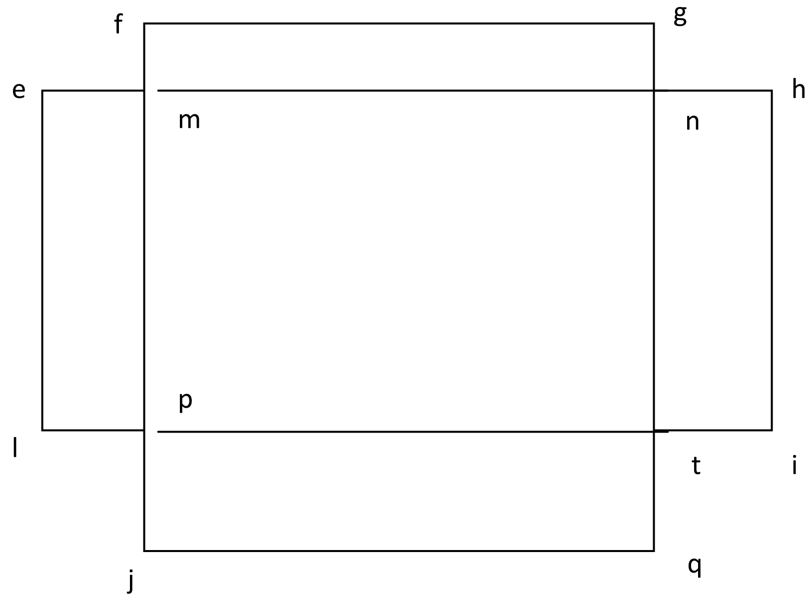

Figure 1.1 Construction of Eulerian Circuit.

Starting at e we might construct C = emnhitple, C'=mfgntqjpm. We insert C' in C at m to obtain the Eulerian circuit emfgntqjpmnhitple.. The mail carrier problem is a classical problem that makes deliveries to each block and returns to the office. The problem is what is the least amount of walking necessary?

The movement of trucks in solid waste management resembles the mail carrier problem. For municipal solid waste system we build a graph H with each vertex representing a stop station (a garbage bin station) and each edge representing a street. We had elegant characterization for Eulerian circuits in the preceding section. Hamiltonian cycles have no known similar characterization. The idea underlying the two concepts are similar; while an Eulerian circuit passes through each edge exactly once, a Hamiltonian cycle passes through each vertex exactly once. Critically examining the two concepts brings their dissimilarities to the fore. While Eulerian circuits may visit a vertex more than once, a Hamiltonian cycle visits a vertex at most once. In short there are no known efficient methods for determining whether simple graphs are Hamiltonian. One approach usually adopted is based on the simple observation that in a simple graph a Hamiltonian cycle contains exactly two of the edges incident with any vertex (otherwise the vertex will be repeated).

The travelling salesperson problem is a classical problem which asks for a shortest Hamiltonian cycle in a given complete weighted graph. The traveling salesperson problem is an important problem that has no known efficient solution. An exhaustive search for all ordering yields the shortest Hamiltonian cycle inefficient. One approach is to settle for an efficient approximation algorithm. We settle for an answer that is close to optimal if we can obtain it using a reasonable amount of computational resources.

Townsend (1987) reported one such algorithms called the Nearest Neighbor Algorithm which constructs Hamiltonian cycles by traveling to the nearest unused vertex. It has the following steps:

Step1: From vertex v_1 and path p_1, repeat step 2 until the nearest neighbor

approximation has been constructed.

Step 2: Given the path $p_k = v_1, v_2, \ldots, v_k$, examine the graph to see if there are any remaining unused vertices. If so then let v_{k+1} be the closest vertex to v_k

(if there is more than one such vertex, choose v_{k+1} arbitrarily) and set

$p_{k+1} = v_1, v_2, \ldots. v_{K+1}$.

1.3 Problem Statement

Solid waste management in Nigeria is characterized by the traditional truck and landfill, budgetary constraints by the solid waste management agencies, lack of coordination of truck scheduling, near zero recycling and compost facilities and arbitrary location of solid waste management facilities.

There is also the delay in deploying garbage trucks. These problems lead to a lot of waste still littering the towns.

The frequent outbreak of such diseases like Cholera, Typhoid and Diarrhea which are associated with improper management of solid waste is a source of concern.

The odor from heaps of unremoved solid waste in many Nigerian towns is a source of discomfort to the teaming population. These heaps have also become a breeding ground for rodents, mosquitoes and organisms that are problems to public health system. Silt and solid waste in some cases cause flooding by blocking the drains and other outlets. There is the problem is improper location of landfills which often lead to underground and surface water contamination. Another problem of the solid waste management system in Nigerian is lack of computer-based approaches to solutions of most functional elements of the system. This usually leads to poor results such as inappropriate landfill selected among potential landfills, repetitive manual tasks which usually result to low productivity among staff of the various solid waste management agencies. The aim of this work is developing a software system that will be used in selecting landfills that lead to minimum pollution.

1.4 Aim and Objectives of the Work.

The aim of the work is to design and implement a landfill location system that selects landfills leading to minimum pollution.

To achieve this aim the following objectives have been identified.

i To conduct a detailed study on how landfills are selected using the current methodology employed by solid waste management agencies in the selected Nigerian cities..

ii To conduct simulation runs with the software system on the selected landfills.

iii Reduce the cost both in time and resources associated with the tedious tasks of selecting landfills manually. The objective here is to reduce the complex tasks of selecting landfills by operators of solid waste agencies to a few keystrokes on the computer system.

1.5 Significance of the Study

The management of solid waste for Nigerian cities is still the traditional truck and landfill system. The location of landfills and other solid waste management facilities is still done arbitrarily. These had led to more pollution in many cases. The work is significant for the following reasons.

i The system selects landfills to minimize pollution among all potential sites by taking into cognizance hydrological and environmental constraints, land use factors and rating of the sites.

ii Provide a quick and efficient method of selecting landfills thereby greatly reducing the time spent by operators of solid waste management on guesses, trials and errors which in most cases result in more pollution.

iii Reduce the cost associated with repeatedly visiting potential landfill sites by operators of solid waste agencies since a geo-database houses the sites as well as their essential attributes.

iv To reduce the high incidence of improper waste disposal related diseases such as typhoid and cholera thereby contributing to the public health system of the nation.

v Provide a means of preventing surface and ground water contamination which go a long way to guarantee safe drinking water.

vi Provide a means of preventing flooding, blocking of drainages and stagnation of water usually associated with improper location of landfills.

vii The work is expected to contribute to the general improvement in the cleanliness of the environment.

1 .6 Scope / Limitation of the Work.

The research work is limited to landfill selection in six Nigerian cities, one each from the geopolitical zones of the country. The towns are Makurdi, Jalingo, Kaduna, Calabar, Enugu and Ibadan. The towns were selected using stratified random sampling method. Liquid and other forms of waste such as nuclear waste are not considered.

The research work is primarily concerned with locating landfills with minimum pollution for Nigerian cities; however, other aspects of solid waste management such as waste collection and transportation are studied since it is difficult studying landfills in isolation of other components of the solid waste management system. The work is not concerned with the chemistry of solid wastes or that of landfills.

CHAPTER TWO: LITERATURE REVIEW

Solid waste management can be very tedious and counterproductive if not properly coordinated. The management of solid waste can be broken down into functional areas. A functional area denotes an activity to be carried out. The functional areas of solid waste management systems are

i Waste collection, storage and transportation

ii Landfilling

iii Waste recycling, composting and incineration

Waste can be turned into wealth through recycling or by the generation of energy through incineration. Waste collection and transportation can also generate employment as garbage truck drivers and waste collectors must be employed. Landfills can also provide employment for host communities. The review of the literature focuses on the functional areas of solid waste management in general. The later part of the chapter is devoted to facility location models.

2.1 Classification of Solid Waste

Many classifications are accorded solid waste. Solid waste can be classified according to sources or types. Hoornweg and Thomas (1999) classify solid waste according to their sources. Their classification is shown in Table 2.1

Table 2.1: Sources of Solid Waste

Source	Typical Waste Generator	Types of Solid Waste
Residential	Single and multifamily dwellings	Food wastes, paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, metals, ashes, special wastes.
Industrial	Light and heavy manufacturing, fabrication, construction sites, power and chemical plants	Housekeeping wastes, packaging, food wastes, construction and demolition materials, hazardous wastes, ashes, special wastes
Commercial	Stores, hotels, restaurants, markets, office building	Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes
Institutional	Schools, hospitals, prisons, government centres	Same as commercial
Construction and demolition	New construction sites, road repair, renovation sites, demolition of buildings	Wood, steel, concrete dirt
Municipal services	Street cleaning, landscaping, parks, beaches, other recreational areas, water and wastewater treatment plants	Street sweepings, landscape and tree trimmings, general wastes from parks, beaches and other recreational areas, sludge
Process(Manufacturing etc)	Heavy and light manufacturing, refineries, chemical plants, power plants, mineral extraction and processing	Industrial process wastes, scrap materials, off-specification products, hazardous wastes like pesticides
Agriculture	Crops, orchards, vineyards, dairies, feedlots, farms	Spoiled food wastes, agricultural wastes, hazardous wastes like pesticides

Source: Hoornweg and Thomas (1999)

Wastes can be classified according to types and whether they are recyclable, composite or can be sent straight to landfills. Table 2.2 depicts this type of classification.

Table 2.2: Waste Types and Associated Activities

Material	Recycling	Composting	Aerobic	Land application	Energy from wastes	Landfill
Paper	Y	Y	Y		Y	Y
Glass	Y				Y	Y
Ferrous Material	Y				Y	Y
Aluminum	Y				Y	Y
Food waste		Y	Y		Y	Y
Yard waste		Y	Y	Y	Y	Y
Others					Y	Y

Source: http//course.civil.ualberta.ca/enve432/Resource CD

Key: Y in a column means such an activity is applicable to a corresponding waste material

Haung et al. (2005) reported the various activities associated with integrated solid waste management. This is summarized in Fig 2.1.

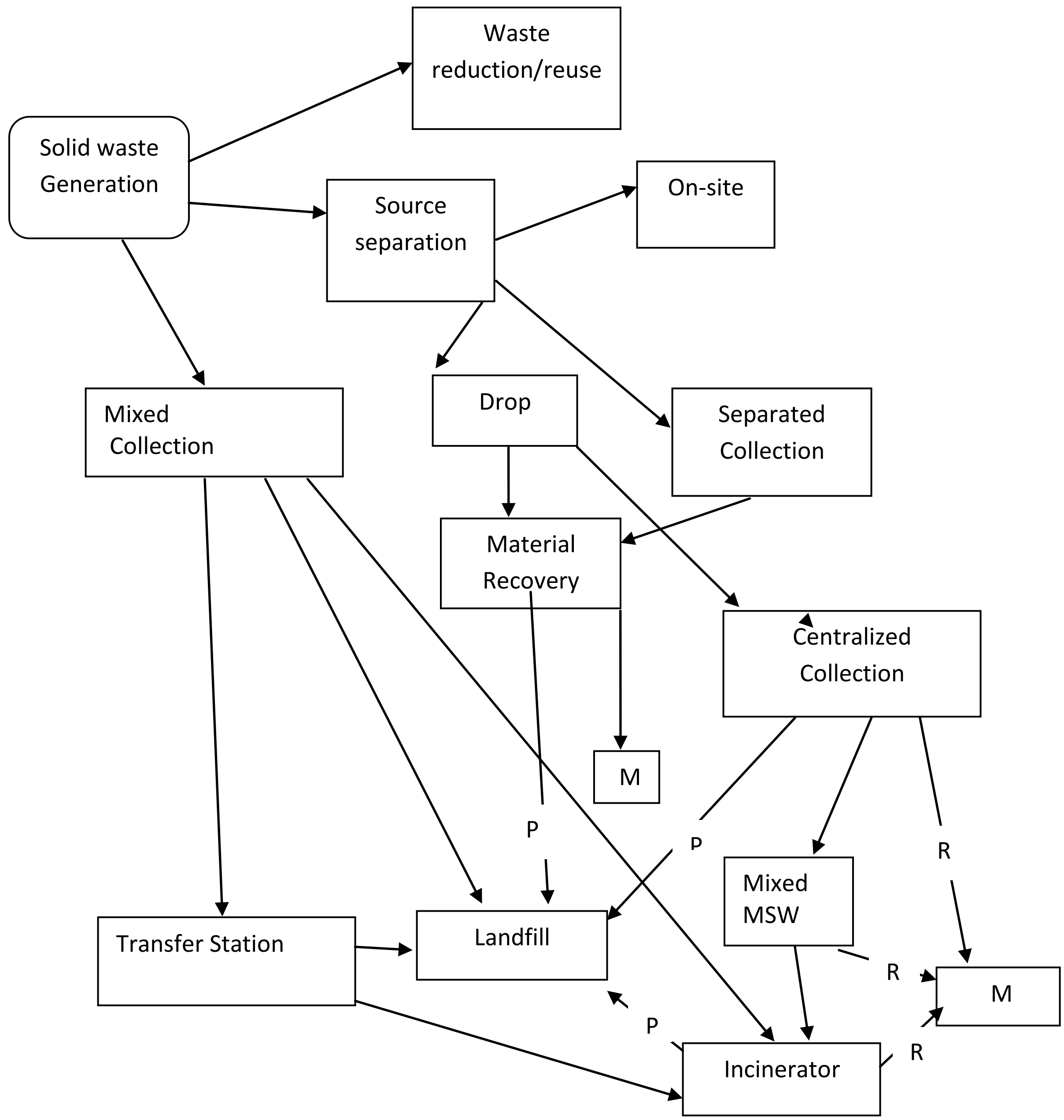

Figure 2.1: Activities in Solid Waste Management

In Fig. 2.1 the solid lines without any label indicate the general solid waste flow. The solid lines labeled R indicate recovered solid waste; the solid lines labeled P represent processed solid waste and rectangles labeled M stand for market or end user. The complex nature of Fig. 2. 1 suggests that a number of activities need to be considered when planning an integrated solid waste management system.

2.2 **Waste Collection and Transportation**

Apaydin and Gonullu(2010) presented a model for stationary container system to estimate collection time based on population density per 100m road distance (LPD_{100}). The model also estimated travel and collection times and the time spent on waiting at stop signs and traffic lights. The model determined the required container number(NC), the number of container locations(NCL) and collection time with stationary solid waste collection(PTC) based on (LPD_{100}). They derived the model parameters using video camera to observe solid waste collection in 39 districts in Trabzon City in Turkey.

The model estimated the required volume for solid waste generation per inhabitant (V_{RP}) to be

$$V_{RP} = \frac{M}{SW_c} \tag{2.1}$$

where M is solid waste generation rate (kg/inhabitant. day), SW_c is average density of solid waste in container(kgm^{-3}).

The required container volume for solid waste generation per household (V_R) was obtained as

$$V_R = P_R \times V_{RP} \tag{2.2}$$

P_R is the number of mean inhabitant per household.

The number of inhabitant per container (P_{NC}) was estimated using the model :

$$P_{NC} = \frac{V_C}{V_{RP}} \tag{2.3}$$

where V_C is the container volume(m^3).

Using the model the average distance between containers(ABDC) was obtained as

$$ABDC = B \times LPD_{100}^{k} \tag{2.4}$$

where B and k are empirical constants estimated based on V_C

The average number of containers (ANC) located in any NCL was obtained as

$$ANC = \frac{NC}{NCL} \quad (2.5)$$

The average speed of collection vehicle (V_{AV}) using recorded data was given as

$$V_{AV} = 5.799 \times Ln(ADBS) - 10.78 \quad (2.6)$$

where ADBS was defined as

$$ADBS = \frac{RDC}{NCL + n_t + n_{ss} + 1)} \quad (2.7)$$

n_t is the number of traffic light per route, n_{ss} is the number of traffic rush per route. RDC is the collection route distance.

The travel time for the entire collection (TTC) was defined as

$$TTC = \frac{f \times RDC}{V_{AV}} \quad (2.8)$$

where f is a conversion factor.

The waiting time for all traffic lights T_t was estimated as

$$T_t = t_t \times n_t \quad (2.9)$$

where n_t is the number of traffic light per route and t_t is average waiting time per traffic light.

Estimate of the waiting time for stop sign T_{ss} was given as

$$T_{ss} = t_{ss} \times n_{ss} \quad (2.10)$$

where t_{ss} is the average waiting time due to stop signs, n_{ss} is the number of stop signs per route.

Estimate of the total route time on a collection route (RTC) for solid waste collection with container from residential was

$$RTC = TTC + PTC + T_t + T_{ss} \quad (2.11)$$

Hung-Yueh et al . (2011) proposed an integer programming (IP) model and ant colony optimization(ACO) to determine an efficient two-shift collection plan that takes into account residential accessing convenience factors. The IP model determined convenient collection points in each shift on the basis of proximity and the ACO algorithm was applied to determine the most effective routing plan of each shift. Their IP model was formulated as

$$Min \sum_{i=1}^{M} \sum_{j=1}^{T} x_{ij} \tag{2.12}$$

Subject to

$$x_{ij} + \sum_{k \in N} x_{k,j} \geq 1 \;\; \forall\, i, j \tag{2.13}$$

$$\sum_{j=1}^{T} x_{ij} \;\; \geq \;\; 1 \quad \forall i \tag{2.14}$$

where i, k are indices of collection points.

M is the total number of collection points

j is the index of the shift, T is the total number of shifts

x_{ij} is a binary variable for which the value is equal to 1 if collection point i is part of shift j, and N is the set of the alternative accessible collection points.

Algirdas and Olga (2010) carried out a survey in Lithuanian localities using people aged 40 years and younger to determine their participation in waste collection. The survey revealed poor participation of public (young people in particular) in collection and sorting of household waste. According to their survey only 37.8% of respondents participated in this undertaking and only 10% do on a regular basis. The survey falls short by not covering the entire population since waste collection is task that cuts across all ages.

Filipiak et al . (2009) used the Chinese Postman Problem(CPP) and k-CPP to evaluate the truck routes and optimum sequence of each of the vehicles needed to collect the generated waste in the Township of Millburn NJ. Each of the three sections of Millburn was divided into four parts under the assumption that each truck stays within its capacity and for each of the four trucks an optimum route was found that minimize the travelled distance. To obtain the lower bound of the travelled distance one truck with unlimited capacity was used. And based on that the optimization of the tours of four trucks each collection zone of the week was studied. The use of unlimited capacity in this algorithm may lead to problems of load balancing among individual trucks.

Nergiz et al. (2009) implemented a network model to optimize and standardize the collection of waste. The objective was to provide waste collection with a route that was near optimal and efficient and at the same time provide a better environment for the public and the workers. They used the following to reach their objective.

i Identify present geographical location

ii Distribute waste container based on a population

iii Find road distances (measure distance between all waste containers)

iv Implement a greedy algorithm to find a route which reduces distances

v Once the algorithm is designed, evaluate the present ergonomic conditions of the workers

vi Implement the new system

Their method could not take into consideration time and capacity of waste containers as constraints.

Eisenstein and Iyer (1997) investigated the scheduling of garbage trucks in the city of Chicago and used a Markov decision process to model the impact on capacity of using flexible routes. The time to collect the garbage from block k was modeled as a normally distributed variable X_k with mean collection time of t_k and a variance in collection time of σt_k.

A constant block dependent parameter, r_k, was defined to represent the rate of garbage collection in pounds per unit time of block k. The mean pounds of garbage picked up from block k was defined as $r_k t_k$ and letting S = {t, t+1… j-1} to be the set of adjoining blocks to be collected by a truck, modeled the total weight capacity of the truck (W). The probability, $\emptyset$, that a truck completes collection of blocks i, i+1, …, j-1 was modeled as

$$\emptyset = \left(\sum_{k=1}^{j-1} X_k \leq T \text{ and } \sum_{k=1}^{j-1} r_k X_k \leq W\right) \tag{2.15}$$

T is the total time available for a truck route. Their method, though suggests a reduction of between 12-16% in the number of truck routes required to pick up all garbage in the system, is silent on the optimal routes to be used by the garbage trucks.

Jing-Quan et al. (2007) reported a prototype decision support system (DSS) that provides solutions for single-depot rescheduling problems (SRP) as well as vehicle scheduling problems (VSP). The DSS used the integration of formation technology and efficient algorithms to solve VSP and (SRP). The DSS included the following requirements:

i To prove an interactive interface that allows the users to retrieve, build and change trips and vehicles database.

ii To obtain optimal solutions for single-depot VSP (SDVSP)

iii To obtain optimal solution for single-depot vehicle rescheduling problem (SDVRP) when an unexpected event occurs

iv To provide an interactive environment to create and modify possible operational scenarios

The components of the DSS are shown in Fig. 2.2.

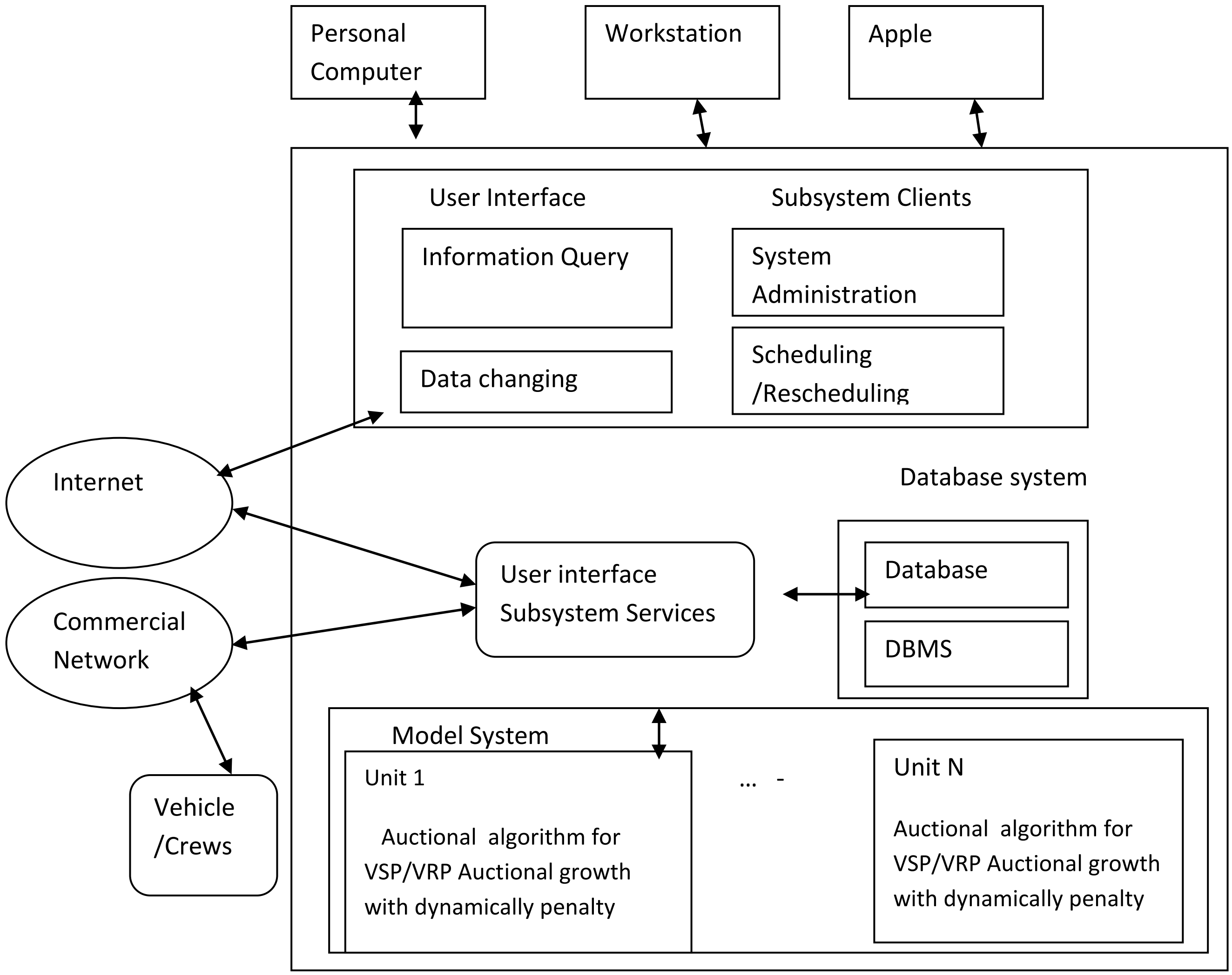

Figure 2.2: The Architecture of the DSS

User interface was a tool for scheduling and rescheduling of vehicles. It included functions to control the flow of information between the modules within the system on the different algorithms within DSS. It provided a meaningful framework within which information can flow in both directions between user and the computer so that user can take full responsibility for the decision. The database subsystem was responsible for management of the databases. The database subsystem had all the information needed for the scheduling and rescheduling of vehicles**.** Examples of data include the following attributes: starting and ending times, starting and ending places, Vehicles (id, Geographical position, crew and capacity), routes (vehicles id and sequence of trips). The database also provided functionality for storing, querying, recovering and controlling data.

The model subsystem was used to solve the classical SDVSP and the SDVRP. The quasi-assignment and auction algorithm were selected for solving SDVSP, since SDVRP was treated as a sequence of SDVSP problems. The quasi assignment formulation and combined forward auction algorithm were used to solve SDVSP within the DSS. The quasi-assignment problem was described as follows:

N = {1, 2… } was defined as the set of trips numbered according to increasing starting time, and Z the set of arcs corresponding to deadheading trips. Letting the vehicle scheduling network be $G = (V, Z)$ with nodes V and arc Z, SDVSP was formulated as:

$$Min \sum_{ij \in Z} C_{ij} y_{ij} \tag{2.16}$$

Subject to

$$\sum_{ij \in Z} y_{ij} = 1 \quad \forall i \in N \tag{2.17}$$

$$\sum_{ij \in Z} y_{ij} = 1 \quad \forall j \in N \tag{2.18}$$

$y_{ij} \in \{0, 1\} \quad \forall i, j \in N$

where C_{ij} is the cost of arc $i, j \in Z$

$$y_{ij} = \begin{Bmatrix} 1 \; if \; a \; vehicle \; is \; assigned \; trip \; j \; directly \\ 0 \quad \text{otherwise} \end{Bmatrix}.$$

The constraint assured that each trip wss assigned to exactly one predecessor and one successor .However, the model has no facility for the scheduling of crews and no restrictions for the number of trips that are rescheduled for a vehicle.

Another model often used in solid waste management is the Ant Colony Route optimization Model. Nikolaos et al. (2005) used the Ant Colony Route optimization model for the best route identification in urban solid waste collection. The model used artificial ants called agents to find good solutions to difficult combinatorial optimization problems. The behavior of artificial ants was based on traits of real ants plus additional capabilities that make them more effective, such as memory of past actions. Each ant of the colony builds a solution to the problem under consideration and uses information collected on the problem characteristics and its own performance to change how other ants see the problem.

The model was based on the following ideas:

i Each path followed by an ant is associated with a candidate solution for a given problem.

ii When an ant follows a path the amount of pheromone deposited on that path is proportional to the quality of the corresponding candidate solution for the target problem.

iii When an ant has to choose between two or more paths, the path(s) with a larger amount of pheromone have a greater probability of being chosen by the ant.

The model is illustrated as shown in the Fig.2.3

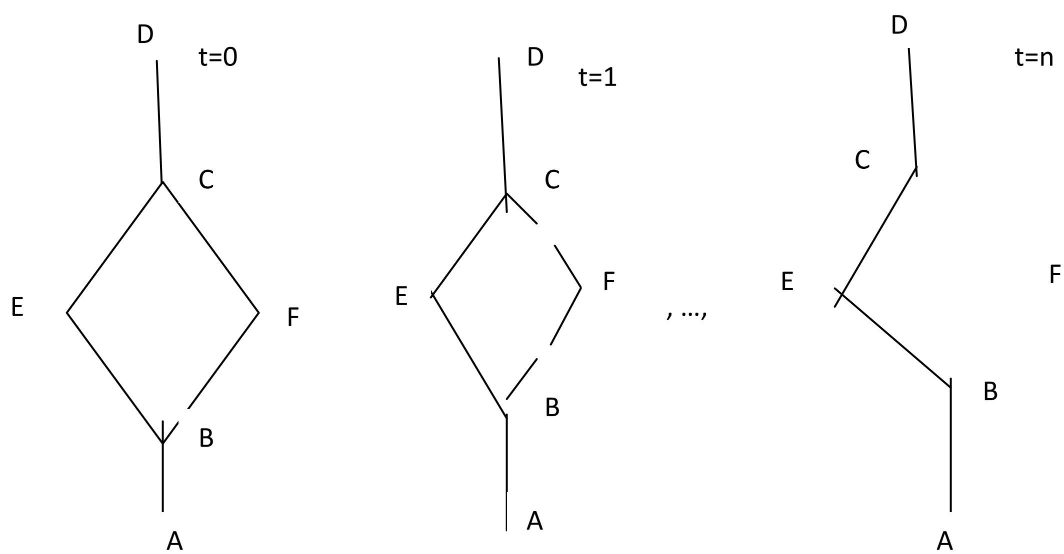

Figure 2.3: Ant Colony Route Optimization Model

Supposed that at time t = 0 a number of ants are moving from point A (colony) to point D (food) as depicted in the Fig.2.3. When the ants arrive at point B they have to choose between routes BEC and BFC. Initially the pheromone trail is same for the two alternative routes, so half of them will choose the first route and the rest the second. The ants which choose the BEC will return in shorter time than the rest of them. That means that the pheromone trail deposited on BEC evaporates less than the BFC route.

At time t =1 ants start again their route to D. When they arrived at B, the pheromone trail in BEC will be stronger than in BFC route, so many more ants will choose the first route. After several cycles the pheromone trail in BFC completely evaporates and all ants choose BEC trail which is the shortest path.

Ismail and Loh (2009) also implemented the Ant Colony Optimization (ACO) for solving the solid waste collection problem as SDVRP model in the city of Johor Bahru in Malaysia. Initially an artificial ant (truck) was placed in every loading spot. The number of ants was equal to the number of loading spots.

Every ant chosed the bin to go to with the probability that was a function of the movement cost between two loading spots and the amount of trail pheromone. Equivalence for pheromone for artificial ants (trucks) was the information on the routes the crews of the various trucks passed to each other. Movements to already visited loading spot were disallowed until a tour was completed. When a tour was completed ants update pheromone on each edge (i,j) they visited. The model placed more emphasis on collection time and not necessarily the distance of the route and may prove inadequate where long distances are involved.

Glover (1986) described the Tabu search as a meta-heuristic. The search iteratively tries to find a solution to the problem but keeps a short list of previously found solutions to avoid re-finding those solutions in subsequent iterations.

Genetic models as reported by Pham and Karaboka (2000) began with a random set of possible solutions. In each step a fixed number of the better current solutions were saved and used in the next step to generate new solutions using genetic operators. Pham and Karaboka (2000) also reported that in simulated annealing an initial solution is generated as the first solution, then the neighboring solutions are generated. If one of the neighboring solutions is better than the current one then it becomes the current one.

Nikolaos et al. (2005) compared the Ant Colony Route optimization Model with genetic, tabu search and stimulated annealing and reported that the Ant Colony Route optimization function slightly better than both tabu search and genetic model. Simulated annealing showed worst results.

2.3 Waste Recycling, Composting and Incineration

Recycling is a process by which waste are transformed either physically or chemically to produce useful items for usage. Ivanus (2010) described the current status of waste of electrical and electronic equipment (WEEE) recycling and its impact on environment, human health and the economy. Their work reviewed the implementation strategies of WEEE treatment and the technologies of WEEE. His work is limited to WEEE and cannot be used in other forms of solid waste mostly found in Nigeria.

Bocci et al. (2010) provided an environmental evaluation of a specific rehabilitation project involving several recycling techniques on one of the main Italian motor ways. Their method was able to reduce material transportation and pollutant emission coming from both the production plant and the means of transport.

Umaru (2010) studied recycling activities in four central states of Nigeria and use the study to examine the contribution of this underground economy of income generation, employment and value addition and confirmed the important role recycling is playing in the local economy of the area.

Daniel (2003) reported that recycling is a manufacturing process with environmental impacts. He reported further that recycling sometimes cut pollution but not always. Huang et al. (2005) reported that the current trends in solid waste management is towards waste reduction, waste reuse as well as recycling of wastes. These activities require facilities. Two costs associated with such facilities are i Fixed charges associated with construction and start –up activities and are independent of its capacity.

ii Costs which are dependent on design capacity. If the design capacity is lower than the maximum allowable level there will be opportunities for future expansion.

Torkashvand (2010) defined composting as a biochemical process converting various segments in organic wastes into relatively stable humus-like substances that can be used as a soil amendment or organic fertilizer. He further investigated the effect of some amendments for improving compost quality produced from municipal wastes.

Stan et al. (2009) reviewed composting methods and concluded that composting is an important element in sustainable waste management, more so, as it is used to treat waste prior to recycling. Irvine et al. (2010) used an in-vessel tunnel composting facility in Scotland to investigate the potential for collection and reuse of compost heat as a source of renewable energy. The amount of energy offered by the compost was calculated and seasonal variations analyzed. They submitted that using the heat of compost was found to provide the most reliable level of supply at a similar price to its rivals.

Gautam et al. (2010) studied the quality of municipal and agricultural wastes under aerobic and anaerobic composting and concluded that nutrient losses are minimum in anaerobic compost. Xie et al. (2010) developed an integral incinerator combining a feeder, a rotary grate, a primary combustion chamber (PCC), a secondary combustion chamber(SCC) into one unit. It has the capability of incinerating 10tonnes of waste per day.

2.4 **Landfills**

Landfills are special facilities that require separate treatment. Ohio state university FactSheet CDFS-138-05 reported that modern landfills are highly engineered containment system designed to minimize the impact of solid waste on the environment and human health. Their work also reported that the greatest threat to groundwater posed by modern landfills is leachate. Leachate consists of water soluble compounds in the refuse that accumulate as water moves through the landfills. Leachate may migrate from landfill and contaminate the soil and ground water thus posing a risk to human and environmental health. Various methods have been proposed or developed to tackle the problem of leachate. Ohio State University FacySheet CDFS-138-05 discussed the various liner systems as explained below.

A liner system could be a single-liner system, composite-liner system and double-liner system. Single-liner systems consist of a clay liner, geosynthetic clay liner or a geomembrane specialized plastic sheeting. These liners are used in landfill designated to hold construction and demolition debris (C&DD). The debris result from building and demolition activities and includes concrete, wood, glass, bricks and asphalts. These landfills are constructed to contain plants, liquid tar and municipal garbage and subsequently this type of liner systems are adequate to protect the environment. Examples of single-liner systems are shown in Fig.2.4

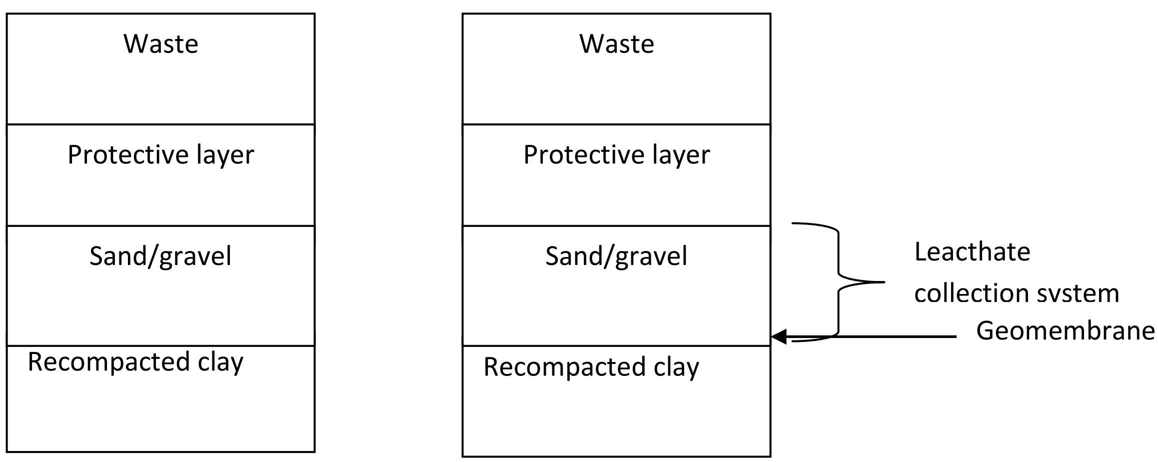

Figure 2.4: Single Liner Systems

Composite liner system: they consist of geomembrane in combination with the clay liner. They are more effective at limiting leachate migration into the subsoil than the single-liner systems. Composite liners are required in municipal solid waste landfills. Municipal solid waste landfills contain waste collected from residential, commercial and industrial services. These landfills may also accept C&DD debris but not hazardous waste. Composite liner systems are as shown in Fig.2.5.

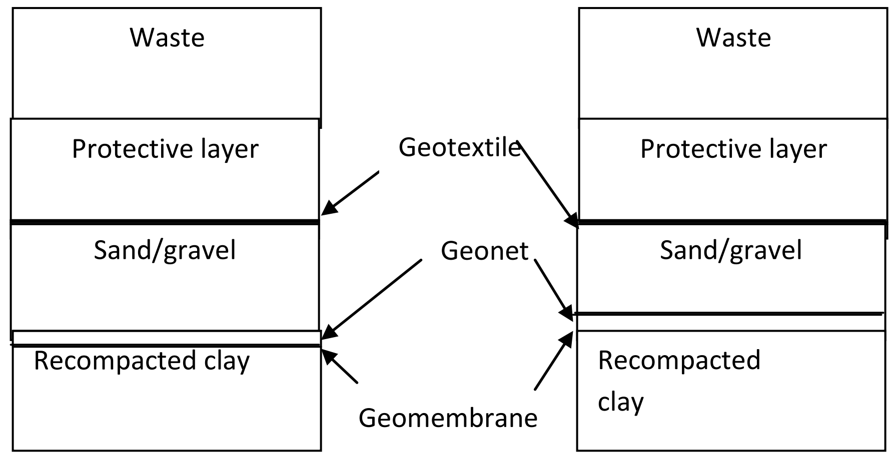

Figure 2.5: Composite Liner System

Double-liner system consists of two single liners, two composite liners or a single liner and a composite liner. The upper (primary) liner usually functions to collect leachate while the lower (secondary) liner acts as a leak-detection system and back up the upper double-liner system are as shown in Fig.2.6.

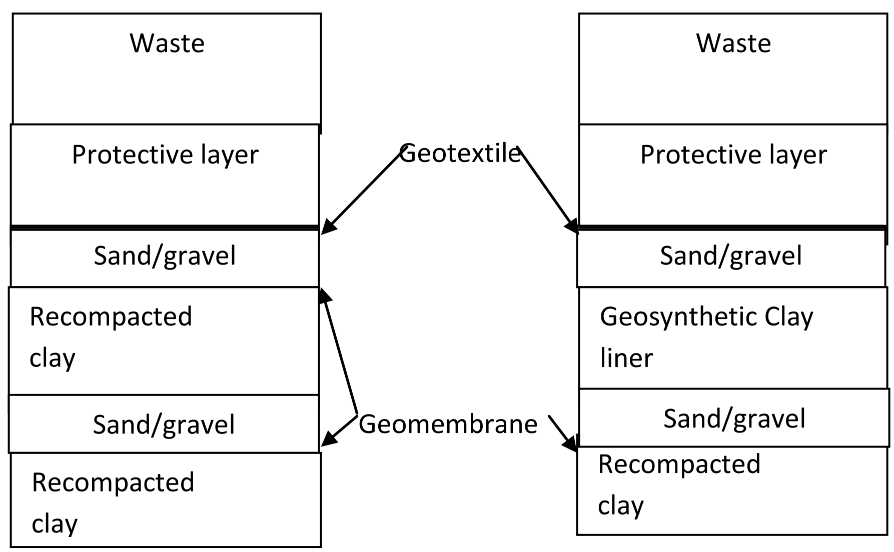

Figure 2.6: Double Liner System

Double liner systems are used in some municipal solid waste landfills and in all hazardous waste landfills. Hazardous waste landfills (secure) landfills are constructed for the disposal of waste that were ignitable, corrosive, reactive and toxic. These wastes have adverse effect on human health and environment if improperly managed.

Leachate collection system: this system is integrated in all liner systems. It is composed of sand and gravel or a geonet. A geonet is a plastic net-like drainage blanket. In this layer it is a series of leachate collection pipes to drain the leachate from the landfill to holding tanks for storage and treatment, eventually. In double-liner system, the primary drainage layer is the leachate collection system and the secondary drainage layer is the leachate collection system . The leach detection contains a second set of drainage pipes. When leachate is present in the secondary pipes it is an alert to landfill management that the primary liner has a leak. The components of a **liner system are:**

Clay: this protects the groundwater from landfill contaminants. It may be three-to-six cm thick. Theoretically two cm of the clay is enough to contain the leachate, the additional clay is to serve as an extra safeguard. Geomembrane are constructed from various plastic materials including polyvinyl chloride (pvc) and high density polyethylene (HDPE). HDPE is preferred because it is strong, resistant to most chemicals and is considered to be impermeable to water. Ohio State University Factsheet (CDFS-138-05 reports that in the USA the thickness of geomembrane used in liners construction is regulated by federal and state laws.

Geotextile is used in liners to prevent the movement of small soil and refuse particles into leachate collection layers to protect geomembrane from puncture. They allow movement of water but trap particles to reduce clogging in the leachate collection system.

Geosynthetic clay liners(GCL) are becoming more common in landfill liner designs. They consist of a thin clay layer four to six millimeters between two layers of a geotextile. These liners can be installed more quickly than traditional compacted clay liners and their efficiency is impacted less by freeze-thaw cycles.

Geonet is a plastic net-like drainage blanket used in landfill liners in place of sand or gravel for leachate collection layer. Sand or gravel are often used due to cost consideration and because geonets are more susceptible to clogging by small particles.

Koukis and Sabatakakis (2008) investigated the environmental problems associated with the development and operation of a landfill site used for municipal solid waste landfilling near the city of Para in Greece. Their findings showed that the lined landfill site was more secure compared to unlined landfill site and they projected that in future there will be several environmental problems from unlined site. In addition they submitted that prevailing hydro geotechnical conditions indicated that the unlined site was a potential source of contamination and extra remedial precautions be taken by the local authorities to prevent severe contamination in soil and groundwater.

Bariaz et al. (2009) suggested the temporally weighted gas collection efficiency was the appropriate way to report gas collection. This value was calculated for a range of decay rates representative of refuse buried in arid and wet areas and for bioreactor landfills.

Schiappacasse et al. (2010) developed design criteria for sanitary landfills which led to a reduction in the stabilization times of municipal solid waste based on experimental results obtained from a pre-pilot scale operation of two sanitary landfills, one with recirculation of leachates treated in an anaerobic digester and the other the recirculation of untreated leachates. The results obtained on the pre-pilot scale showed that recirculation of an aerobically treated leachates when compared with the recirculation of untreated leachates increase the rate of municipal solid waste stabilization.

All the models encountered in this section assumed that a landfill was already selected and as such have no provision for facility location. In short the models applied only to existing facilities and as such are not of great importance in the process of selecting a landfill.

2.5 Integrated Approach to Solid Waste Management

Discussions in the previous sections mostly centered on individual functional element of solid waste management. In this section we shall examine the integrated approach to solid waste management.

Rathi (2007) developed a linear programming model for integrated waste management planning. His objective function and model constraint were derived taking into consideration both economic and environment costs.

The objective function included minimization of net cost of integrated solid waste management system. The objective function was formulated as

$$Min(CT - BT) \qquad (2.19)$$

Where CT is total cost associated with integrated solid waste management stream and BT is the total benefit associated with integrated solid waste management stream.

Alidi (1996) proposed a multi objective optimization model based on goal programming to assist in the proper management of hazardous waste generated by petrochemical industry. The model combines the analytic hierarchy process (AHP) and a decision –making approach incorporating qualitative and quantitative aspects of a problem to prioritize the conflicting goals usually encountered in addressing waste management problems in a petrochemical industry. Such formulation can be adopted for use in solid waste management. The model seeked an optimal compromise between several conflicting objectives. The model was applied to hazardous waste. If the model is to applied in solid waste management it will involve substantial revision.

Agunwamba (2001) formulated an integrated solid waste collection model. His objective was to minimize the total cost associated with waste collection.

Denoting i, j and k as indices for generation, transfer and disposal sites, respectively he obtained the following parameters and variables.

X_{ij} = the daily solid waste to be removed from generation node i to transfer station j.

Y_{ik} = the amount of daily solid waste to be removed from generation node i to disposal site k.

z_{jk} = amount daily solid waste to be removed from transfer station j to disposal site k and

d_j = a zero-one variable which takes the value of 1 if a transfer station is to be set up at candidate location j.

The constraints of waste collection:

$$W_i = \sum_{j=1}^{n_t} X_{ij} + \sum_{k=1}^{n_d} Y_{ik}\,, i = 1, 2, \dots, n_g \tag{2.20}$$

where W_i is the daily waste generated at generation node i

$$\sum_{i=1}^{n_g} X_{ij} \le T_j, \qquad j = 1, 2, \dots, n_t \tag{2.21}$$

where T_j is the daily processing capacity of transfer station j. This means all solid waste moved to transfer station j must be less or equal to the processing capacity of transfer station.

$$\sum_{i=1}^{n_g} X_{ij} - \sum_{k=1}^{n_d} Z_{jk} = 0, j = 1, 2, \dots, n_t \tag{2.22}$$

ensures that the amount of solid waste removed from generation node i to transfer station j is the same as the amount moved from transfer station j to disposal site k.

$$X_{ij} - Ld_j \le 0, i = 1, 2, \dots, n_g, j = 1, 2, \dots, n_t \tag{2.23}$$

ensures that there will be activity at candidate location $X_{ij} > 0$ iff a transfer station is setup there. L Represents sufficiently large amount which will make the constraint non binding whenever $d_j = 1$.

$$\sum_{i=1}^{n_g} Y_{ik} + \sum_{j=1}^{n_t} Z_{jk} \le U_k, k = 1, 2, \dots, n_d \quad (2.24)$$

ensures that the amount of solid waste sent to each disposal site will not exceed the processing capacity of that site.

The objective coefficients were defined as:

a_j as the daily operating and investment cost of transfer station j.

t_{ij} as the cost of carrying one tonne of solid waste from generation node i to transfer station j.

U_{ik} as the cost of carrying one tonne of solid waste from generation node i to disposal site k.

C_{jk} to be the cost of carrying one tonne of solid waste from transfer station j to the disposal site k.

The problem is to minimize the total cost Z. This problem can be stated as:

$$Min\ Z = \sum_{j=1}^{n_t} a_j d_j + \sum_{i=1}^{n_g} \sum_{j=1}^{n_t} t_{ij} X_{ij} + \sum_{i=1}^{n_g} \sum_{k=1}^{n_d} U_{ik} Y_{ik} + \sum_{j=1}^{n_t} \sum_{k=1}^{n_d} C_{jk} Z_{jk} \quad (2.25)$$

subject to the following to the following

$$\sum_{j=1}^{n_t} X_{ij} + \sum_{k=1}^{n_d} Y_{ik} = W_i, i = 1, 2, \dots, n_g \quad (2.26)$$

$$\sum_{i=1}^{n_g} X_{ij} \le T_j, j = 1, 2, \dots, n_t \quad (2.27)$$

$$\sum_{i=1}^{n_g} X_{ij} - \sum_{k=1}^{n_d} Z_{jk} = 0, j = 1, 2, \dots, n_t \quad (2.28)$$

$$X_{ij} - Ld_j \leq 0, i = 1, 2, \dots, n_g, j = 1, 2, \dots, n_t \tag{2.29}$$

$$\sum_{i=1}^{n_g} Y_{ik} + \sum_{j=1}^{n_t} Z_{jk} \leq U_k, k = 1, 2, \dots, n_d \tag{2.30}$$

$$X_{ij} \geq 0, Y_{ik} \geq 0, Z_{ik} \geq 0, i = 1, 2, \dots, n_g, j = 1, 2, \dots, n_t, k = 1, 2, \dots n_d \tag{2.31}$$

$d_j = 0, 1$

2.6 Facility Location Problem

This is a complex problem for operators of solid waste management systems and is the main focus of the research. The various sites needed in an integrated solid waste management system include sites for waste bins, landfills and waste processing facilities like waste recycling. By far the most important of these facilities is landfill. This is basically because of its ability to not only contaminate the ground and surface water but the environment if poorly selected. The models of facility location are variously discussed by Berman and Krass (2005), Javid and Dawoudpour (2009), Suzuki and Hodgson (2003).

A new model for single facility location based on service level (FLSL) due to Javid and Dawoudpour (2009) has the following Parameters.

m is the number of customer or previously located facilities.

(x_i, y_i) is the location of the ith customer or the ith previously located facility where i =1, 2, …, m.

dd is a given parameter representing the desirable distance for all the customers.

The decision variable was defined as

(x, y) which is the location of the new single facility.

The objective of their model was to maximize the mean number of customers whose distance from the new facility was smaller than the desired distance dd. The problem was formulated as

$$Max_{(x,y)}\ E\{N(x,y)\} \tag{2.32}$$

where N(x,y) denotes the number of satisfied constraints in the set of uncertain constraints

$$N(x,y) = \{\| \ (x_i - \ x, y_i - y)\} \ \|_2 \leq dd, i = 1, 2, \dots, m \tag{2.33}$$

The optimization problem formulated is a nonconvex problem and cannot be solved globally unless direct search method is used.

Javid and Dawoudpour (2009) further developed a mixed integer convex program to approximate $E\{N(x,y)\}$.

The approximation for $E\{N(x,y)\}$ was given as

$E\{N(x,y)\} = n(x,y)$ where $n(x,y)$ is the number of satisfied constraints in the set

$$N(x,y) = \{E(dd^2 - \| \ x_i - x, y_i - y \ \|_2^2)\} \geq 0, i = 1, 2, \dots, m\ . \tag{2.34}$$

Berman and Krass (2005) examined the standard Uncapacitated Facility Location Problem(UFLP) whose parameters were defined as follows.

N = {1…n}: is a set of customers that require services from facilities.

X = {1…x} :is a finite set of potential facility locations.

f_x: is the cost incurred opening a facility at locations x ϵ X

$m \geq 1$: is the maximum number of facilities that can be opened.

$c_{ix}, i \in N, x \in X$ is the benefit of serving customer i at facility x.

Their model used the following decision variables.

$$S_x = \begin{cases} 1, if\ facility\ is\ located\ at\ x \in X \\ 0, otherwise \end{cases}$$

$$Y_{ix} = \begin{cases} 1, if\ customer\ i\ \in N\ is\ served\ by\ facility\ located\ at\ x \in X \\ 0, otherwise \end{cases}$$

They formulated the problem as

$$Max \sum_{i=1} \sum_{x \epsilon X} c_{ix} Y_{ix} - \sum_{x \epsilon X} f_x S_x \qquad (2.35)$$

subject to

$$\sum_{x \epsilon X} S_x \le m\ . \qquad (2.36)$$

ensures that no more than m facilities are located.

$$S_x \ge Y_{ix}, i \epsilon N, x \epsilon X \qquad (2.37)$$

ensures that a customer can only be served from an open facility.

$$\sum_{x \epsilon X} Y_{ix} \le 1, i \epsilon N \qquad (2.38)$$

ensures that each customer is served by at most one facility.

Berman and Krass(2005) further observed that the objective function coefficients have a special structure called level set. They used this structure to define a new set of binary decision variables $Y_i^j, i \epsilon N, j = 1, 2, \dots, L_i$ as

$$Y_i^j = \begin{cases} 1, if\ customer\ i\ is\ served\ by\ a\ facility\ in\ level\ set X_i^j \\ 0, \quad otherwise \end{cases}$$

where L_i are distinct values of the objective function coefficients and X_i^j are called the j[th] level set for customer location i.

They also obtained the following alternative formulation

$$Max \sum_{i=1}^{n} \sum_{j=1}^{L_i} c_i^j Y_i^j - \sum_{x \in X} f_x S_x \tag{2.39}$$

subject to

$$\sum_{x \in X} S_x \leq m \ . \tag{2.40}$$

$$\sum_{x \in X} S_x \geq Y_i^j, i \in N, j \in \{1, 2, \dots, L_i\} \tag{2.41}$$

specifies that a customer can only be covered from level set j if there is at least one open facility in this set.

$$\sum_{j=1}^{L_i} Y_i^j = 1, i \in N \tag{2.42}$$

ensures that a customer is covered from some level set, the objective function will ensure that the customer is covered at the best available level.

$$S_x, Y_i^j = 0, 1 \ i \in N, x \in X_i^j, j \in \{1, 2, \dots, L_i\} \tag{2.43}$$

where c_i^j is the j[th] distinct value of c_{ix}

$X_i^j \subset X, j = 1, 2, \dots, L_i$ is defined by

$$X_i^j = \{x \in X: c_{ix} = c_i^j\} \tag{2.44}$$

and also called the j[th] level set for customer location i.

The new formulation has all the desirable properties of the standard formulation but with substantially smaller dimensionality which leads to significant improvement in computational times.

Suzuki and Hodgson (2003) discussed the location – allocation models that generated facility systems that were optimally accessible to the population demanding the services.

The widely used model of this type is P-median which locates facilities to minimize the distance from the demand populations. In the discrete space P-median demand is perceived as being expressed as a number of discrete points. The model used integer programming formulation, the problem was to minimize Z, which described the total demand –weighted distance between demand points and the nearest facility as follows:

$$Min\ Z = \sum_{i=1}^{m} w_i \sum_{j=1}^{n} d_{ij} x_{ij} \tag{2.45}$$

where m is the number of demand points indexed i, n is the number of potential facility location points indexed j some or all of these maybe co-terminus with the demand points

w_i is the demand weight at i

d_{ij} is the distance between $i\ and\ j$

$x_{ij} \in \{0,1\}$ and equals to 1 if the demand at i location allocates to facility at $j, 0$ if not .

They define the following constraints.

$$\sum_{j=1}^{n} x_{ij} = 1, \forall i \tag{2.46}$$

i.e. the total demand for each i must be allocated to the facility exactly once.

$$x_{ij} \le x_{jj}, \forall i, \frac{j}{i} \ne j \tag{2.47}$$

i.e. the demand at i maybe served by facility at j only if one exists. If a facility exists at j there is the guarantee that it will serve customers at the same location. Hence $x_{jj} = 1$ indicats that a facility exist at j. If a facility exists at location j there is no guarantee that it will serve customers at location i , where $i \ne j$.

$$\sum_{j=1}^{n} x_{jj} = P \tag{2.48}$$

The total number of facilities is P where P is the desired number of facilities.

Pasquale et al. (2009) proposed a simple and effective heuristic method for large scale capacitated facility location problem(CFLP) based on Lagrangean relaxation method used to select a subset of variables forming the core problem and on a Branch –and-Bound method that solves the core problem. The primary motive of this model was to minimize financial cost and had no such provision for minimizing pollution. The model may not be applied in locating landfill without modifications.

Shiode and Ishii(1991) examined a stochastic facility location model called A-distance model in which weights of demand points were not deterministic but independent random variables and whose objective was to find a solution which minimize the total cost criterion subject to a chance constraint on cost restriction. The following parameters were defined.

$Q_i, i = 1, 2, \dots, m$: to be demand points on a plane

X: to be the location of the facility on the plane

$d_A(X, Q_i)$: to be the A-distance between the facility and the i[th] demand point.

W_i : the weight which converts the distance $d_A\ (X, Q_i\ )$into cost. The assumption was that weights have independent normal distribution with positive mean μ and variance σ_1^2.

A is the set of m orientations $a_1, a_2, \dots, a_m$ such that $a_{1\leq} \leq a_2 \leq a_3 \leq \cdots \leq a_m$.

An A-oriented line(or half line) was defined as a line whose orientation is one of $a_i, i = 1, 2, \dots, m$

An A-distance for any $Q_1, Q_2\ \epsilon\ R^2$ to be was formulated as

$$d_A(Q_1, Q_2) = \begin{Bmatrix} d_2(Q_1, Q_2)\ if\ Q_1\ and\ Q_2\ lie\ on\ A - oriented\ line \\ min_{Q_3}\{d_A(Q_1, Q_2) + d_A(Q_3, Q_2)\ otherwise \end{Bmatrix} \tag{2.49}$$

where $d_2(Q_1, Q_2)$ represents the Euclidian distance.

They formulated a model whose objective is to locate a single facility to minimize the total cost criterion(r) which is satisfied with at least the probability $\beta(> \frac{1}{2})$.

Their formulation was given as, $Min\ r$

subject to

$$\Pr\{\sum_{i=1}^{n} W_i d_A(X, Q_i) \leq r\} \geq \beta \tag{2.50}$$

where Q_i is the location of the i^{th} demand point and X is the location of the facility to be determined.

The model was used to minimize the total cost(financial cost) and may not be suitable in locating landfills where major consideration is not only financial cost but such issues like drainage pattern and other hydrological criteria are used.

Johnson et al. (2005) presented alternative hierarchical facility location models for senior centers in Allegheny county in Pennsylvania in order to minimize consumer disutility and unserved demands among elderly people. The aim here was to minimize distance and cost at the same time. This type of model can be used in establishing centres that provide such services as lunch time meals and entertainment. Many other criteria useful in locating landfills are left out from the model.

Bigotte and Antunes(2007) reported a model that minimizes the demand-weighted total distance. Using indices j and k to stand for demand set and set of sites where facilities may be located respectively they formulated the problem as

$$Min\ D = \sum_{j \epsilon J} \sum_{k \epsilon K} u_j d_{jk} x_{jk} \tag{2.51}$$

Subject to

$$\sum_{k \in K} x_{jk} = 1 \quad \forall j \in J \tag{2.52}$$

$$x_{jk} \leq y_k \quad \forall j \in J, \qquad k \in K \tag{2.53}$$

$$\sum_{j \in J} u_j x_{jk} \geq z_{min} y_k \quad \forall k \in K \tag{2.54}$$

$$\sum_{i \in K} x_{ji} \geq y_k \quad \forall j \in J, \quad k \in K \tag{2.55}$$

$$x_{jk} \in \{0.1\} \; \forall j \in J, \quad k \in K \tag{2.56}$$

$$y_k \in \{0, 1\} \quad \forall \, k \in K \tag{2.57}$$

where D stands for demand-weighted total distance,

u_j is demand at each centre $j \in J$

y_k is a decision variable for locating a facility, y_k = 1 if a facility is opened at location k and 0 otherwise.

The decision regarding the assignment of demand to facilities were represented by x_{jk}, $x_{jk} = 1$ if demand centre j obtains service from facility location k and 0 otherwise.

d_{jk} is the shortest travel distance(or cost) between demand centre j and facility location k.

This model seeks to minimize travel time or travel cost. While minimization of travel time or distance is also desirable for landfills location, using it as the sole criterion will leave out environmental, land-use and hydrological criteria used in locating landfills. Thus the application of the model and any other model in the category directly in selecting landfills without modification or integration with other models will lead to a lot of pollution.

Agaji and Wajiga(2010) proposed an object oriented system that selects landfills that led to minimum pollution. The system checked the hydrological and environmental criteria of potential landfills. A further test on the potential landfills using land use criteria was carried out. The final test used a set of miscellaneous criteria like economic impact to select the suitable site(s).

2.7 Fuzzy model

The underlying concept here is the Fuzzy sets. Fuzzy set is superset of traditional set. It uses the concept of partial truth values between completely true and completely false. Mapping displays geographical phenomena do not conform to sharp boundaries imposed by the traditional logic. Fuzzy set utilizes subjective or qualitative reasoning. Fuzzy member values with respect to landfill selection for map objects are obtained by considering the relative importance for suitability for a landfill.

Gupta et al. (2003) reported a Fuzzy relation impact analysis technique for landfill selection. They defined three universes, that is, frequency of occurrence, adverse consequence and impact and obtained the fuzzy relations among them and used the relations to locate landfills.

Zadeh(1965) explored, in a preliminary way, some of the properties and implications of fuzzy set and its use. According to him if X is a universal set of elements x and A the subset of X, each element x is associated with a membership value $f_A(x)$ to the subset A in the interval (0, 1). If A is a Fuzzy set it may be represented by m discrete values of x together with its membership values f_A as

$$A = [x_1 f_A(x_1), x_2 f_A(x_2), \ldots, x_m f_A(x_m)] \tag{2.58}$$

The nature of the spatial data requires this type of model for analysis. In the tradition set theory membership of elements resembles Boolean variables whereas in Fuzzy sets the degree of membership is the issue of concern. Since we are dealing with sites that may not wholly meet the selection criteria the fuzzy set is preferred. A Fuzzy set is a class of objects with a continuum of grades of membership. The set is characterized by a membership function which assigns to each object a grade of membership ranges between zero and one.

Hagemeister et al. (1996) proposed the use of multicriteria assessment tool as a system for screening and prioritizing unregulated disposal sites according to their level of environmental and health hazard. This multicriteria assessment system used a technique termed composite programming and allowed for the use of imprecise information through fuzzy set theory. The assessment procedure utilized fuzzy composite programming(FCP) to aggregate the individual hazards into a final overall hazard for a site. In addition to determining the hazard that an individual site possesses, the fuzzy tool was used to rank several landfills based on their relative degree of hazard.

Seo et al. (2003) proposed a systematic approach to evaluating a solid waste management in a fuzzy environment. Their approach employed three concepts: linguistic variables, fuzzy numbers and an analytic hierarchy process. Linguistic variables were used to represent the degree of appropriateness of decision criteria which were vague or uncertain. The linguistic variables were then translated into fuzzy numbers to reflect their uncertainties and aggregated into final fuzzy decision value using a hierarchy structure.

The objective of using Fuzzy sets was to help in the decision process to select the most appropriate landfill from different candidate sites. A set of different alternative landfills , A, was defined as $A=\{A_1,A_2,...,A_n\}$ and a set of decision variables, B, was defined as $B = \{B_1,B_2,...,B_n\}$ where for example B_1 = Ecological and environmental issues, B_2 = public nuisance, B_3 = Transportation issues, B_4 = Economic impact of facility. Fuzzy sets converted linguistic values into numeric values. For example the sites assigned weights as very good, good and poor can be represented in a Fuzzy with their corresponding membership values as illustrated below.

Very good (v) = (0.8|0.7, 0.9|0.9, 1.0|1.0)

Good (g) = (0.5|0.55, 0.6|0. 6, 0.6|0.68)

Poor (p) = (0.1|0.22, 0.2|0.3, 0.3|0.4, 0.4|0.45).

To select the most suitable landfill site each alternative landfill is weighed against the criteria as shown in Fig.2.7

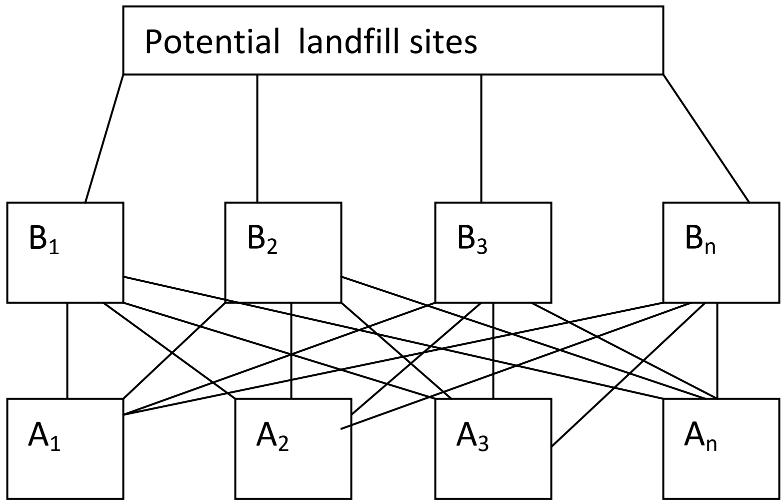

Figure 2.7: Decision model for Site selection

In Fig 2.7 all the decision variables (Bi) are applied on each potential site(Ai).

CHAPTER THREE: MATERIALS AND METHODS

3.1 System Analysis

Site analysis for the location of landfills is a very complex problem for operators of solid waste management systems and is the main focus of the research. The various sites needed in an integrated solid waste management system include sites for waste bins, landfills and waste processing facilities like waste recycling facilities. Currently in all the cities studied, the sites were arbitrarily chosen without any scientific methodology. These arbitrary choice of sites had led to more pollution problems. The process of locating landfills that leads to minimum pollution involves collecting data on such potential sites and applying a methodology to select the desired landfill under certain constraints. To understand the existing system with the view of designing a new and more efficient method, a system analysis was carried out.

A detailed study of the existing system was carried out with the aim of detecting its loopholes and weaknesses. This was also done with the view of developing new systems to replace existing ones. In order to have a clear view of what is obtainable in the solid waste management systems of the selected Nigerian cities the following methods were used:

i Oral interview were conducted on the staff of urban and sanitation agencies and in some cases the staff of the state and federal ministries of environment.

ii Observations were also carried out on the activities of the staff of the above mentioned organizations.

iii In some cases the policy documents were studied in order to fully understand the policy and working mechanism of the agencies charged with solid waste management.

The study covered six cities namely Makurdi, Enugu, Calabar, Kaduna, Jalingo, and Ibadan. These towns were selected from each of the six geo-political zones of Nigeria using stratified random sampling method. The study reveals the following

Consideration was not given to factors determining the location of mammoth and dinosaur waste bins. In some cases waste bins are sited near flooding areas.

A waste bin capacity was also not a major consideration in some cases and the frequency of the removal of wastes was not also a major consideration in some cases. This leaves wastes to litter around the bins with the attendant problems of flies and mosquito breeding and bad odour.

There was nothing like systematic truck scheduling and monitoring in all the cities covered by the research and as such huge cost is incurred by most solid waste management agencies on the operation and maintenance of garbage trucks. There was no mathematical/computer model guiding the movement of trucks in the course of waste removal.

All the towns under study implement a truck and landfill method of waste management whereby a truck leaves a garage to any of the waste bins, as directed or assigned, picks up wastes and heads straight to a landfill. Such directives are mostly ad-hoc in nature and are not scientifically coordinated.

The process of picking wastes and land filling continues throughout the working hours of the day. Thereafter the truck returns to its garage. This activity is repeated five to six days a week leaving wastes to accumulate on Sundays (and Saturdays in some cases). Truck drivers in some cases use longer distances in the course of transporting wastes to landfills or travel through traffic congested routes. This is especially true for Kaduna, Enugu and Calabar towns.

In all the towns studied, waste separation was not carried out such that recyclable wastes such as paper, plastics were picked and dropped at landfills and in most cases burnt to ashes or left to litter. Waste separation by hand at household level which is the most important criterion if wealth can be generated from wastes was not carried out.

Currently, transfer stations were absent in all the towns covered under the study. Transfer stations provide an avenue for temporary disposal of large amount of solid wastes which are later moved to landfills or other waste processing facilities.

In all the cities studied household wastes account for more than 75% of the total tonnage of wastes with the remaining waste coming from hospitals, offices, industries and farm settings. Waste are initially disposed using very small household bins and moved to bigger waste bins where garbage trucks can carry it to a landfill.

Site analysis has to be carried out before siting any solid waste facility. Solid waste facilities are landfills, recycling centres, and composting centres. In all the cities covered under the study, it was observed that, systematic site analyses were not carried out before locating landfills which are the most dominant facility.

Path analysis was also not undertaken in any of the cities under study. Path analysis evaluates a path with minimum impedance between stations on the solid waste graph network. The path may be between an originating node and a destination node for a solid waste system. The analysis helps garbage truck drivers in effectively carrying out their activities of delivering wastes.

No clear mathematical model was identified in the cause of the analysis of the solid waste management systems. The traditional truck and landfill system was the only system used. In the truck and landfill system a truck driver leaves the garage, picks up wastes from any of the waste bins and heads straight to the landfill. No systematic optimization models were used to bring down the cost of waste management activities.

The method used by the solid waste management agencies in Nigeria is a truck and landfill system with minor incineration centres and this is illustrated in Fig.3.1. In Fig.3.1, G stands for generation site T stands for transfer station and D for destination sites. A good example of a destination site is a landfill. A destination site can also be an incineration centre.

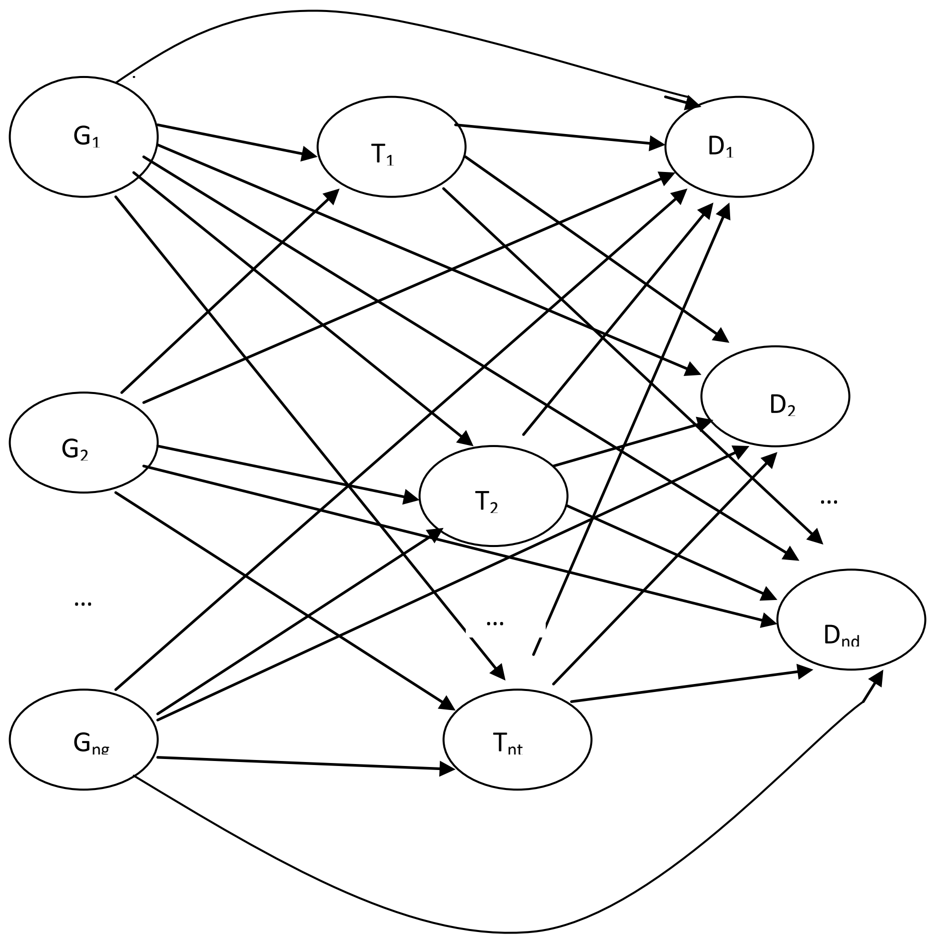

Figure 3.1 Integrated Model for SWM for Nigerian cities

3.2 Design

The frame work of the design phase is captured in the Fig. 3.2

It can be deduced from Fig.3.2 that the design process is an iterative process.

The software system under development has four principal modules.

These are

i A module for carrying out hydrological and environmental analysis.

ii A module for carrying out Land-use analysis.

iii A module for carrying out analysis for another set of miscellaneous analysis.

iv A module for carrying location analysis which spells out the location of the site on the surface of the earth.

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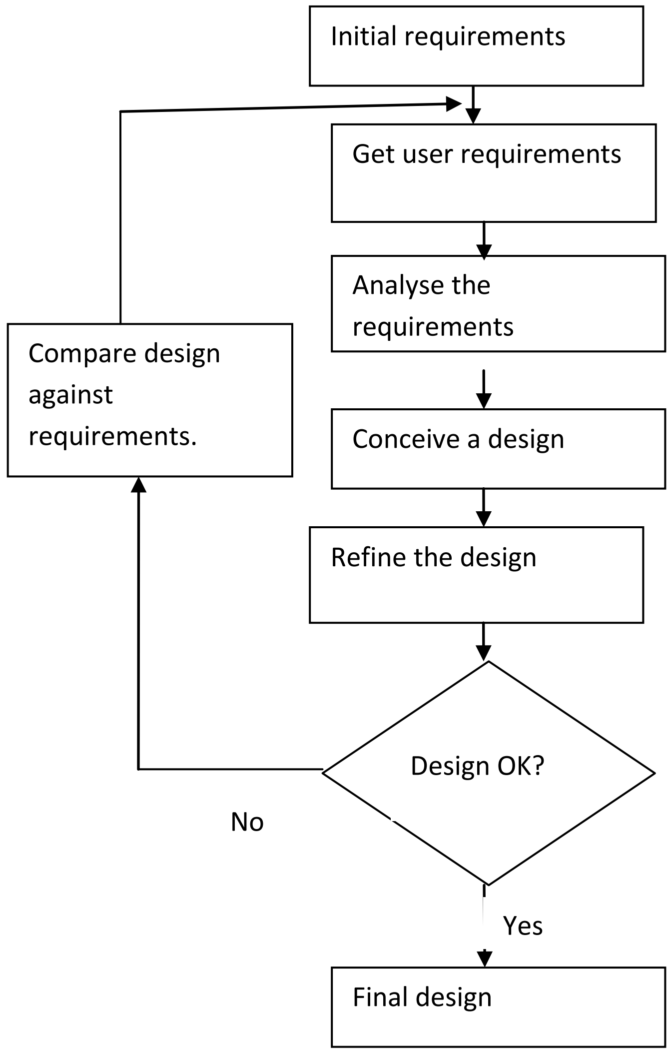

Figure 3.2: Design Framework

The modules were examined to determine the nature of coupling applicable to them. Coupling measures the degree of interdependence between the modules. Common coupling exists between the modules. This is the type of coupling where two or more modules interact to share a common set of data. Apart from sharing a set of common data the modules are independent.

Another form of coupling that exists between the modules is data coupling.

Data coupling exist between modules if their interdependency is based on the fact that they communicate by only passing data.

Control coupling occurs between modules if they communicate by passing control information. External coupling occurs between modules if one of the modules is external to the software underdevelopment.

3.2.1 Data structure

The nature of integrated solid waste data calls for discussion on geographically referenced data. This type of data is different from other types of data in that it has two components: the spatial component and an attribute.

The spatial data spells out the location whereas the attribute data spells out the characteristics of a location. A house for example has a spatial data which spells out where it is located and its characteristics could be its name.

Spatial data could be continuous or discrete but in the design of the integrated solid waste management system, discrete spatial data will be more useful. Discrete spatial data are individually distinguishable like points, roads and areas in land use types. Table 3.1 is an example of geographically referenced data.

Table 3.1 Geographically Referenced Data

Name	Shape	Object-id	Location	$Category_1$	…	$Category_n$	Area(M^2)
$Site_1$	Rectangle	001	(x1, y1)	0.3	…	0.2	1000
$Site_2$	Triangle	002	(x2, y2)	0.3	…	0.2	2000
…	…	…	…	…	…	…	…
$Site_n$	Circle	00n	(xn, yn)	0.7	…	0.3	3000

In the above table Object-id stands for an object identifier which is the name given to an area in question which could be a timber shade, a market or a motor park. Shape identifies the shape of the object using any of the polygons like rectangles and triangles. Object-id is a unique identification of all the sites in a given town. No two areas are allocated the same Object-id. The categories spell the land use type. Land use type is a very important issue especially in the location of solid waste facilities like landfills. Various categories of land use types were captured in the course of modeling the data. Examples of land use types examined are residential, flooding, roads, virgin land. For example a given land could be partially used for a road and for some residential houses. The data examined were distances in metres. That is if there is a distance of zero(0) metre from a potential site to residential houses it means the site is found within the residential houses and is not suitable landfill.

3.2.2 Input table

Fields have to be defined for them to be used in the tables. The definition covers field name, type (e.g. numeric, character), width and number of decimal places (for numeric fields). Widths specify how characters will be contained in field values. The fields were defined. Most fields were defined to be numeric in nature; few were defined to be character in nature. The fields defined for the location were character used to represent degrees, minutes and seconds.

A database was created and five tables defined in the database. These tables HGL which holds the hydrological and environmental attributes of sites. The individual attributes defined in this table are:

i Distance of the site (in metres) from erosion sites denoted by gq in the table

ii Depth (in metres) of water table denoted by wt in the table

iii The degree of infiltration of the soil (on a scale of 1 to 100) denoted by de in the table iv The degree of elevation (on a scale of 1 to 100) denoted by di in the table

v Sites which provide an identity to the various sites in the table.

The first four attributes of the table are numeric in nature and the fifth is alphanumeric in nature. The second table defined in the database is called LUC and it holds the land use attributes of the various sites. It has the following attributes

i Distance of the site from road network denoted by rn

ii Distance of the site from water bodies denoted by wb

iii Distance of the site from arable land denoted by al

iv Distance of the site from settlement denoted by s

v Distance of the site from sensitive sites denoted by ss

vi Distance of the site from waste land denoted by wl and

vii Sites which provide identity to the various sites.

The first six attributes are all distances (in metres) and are numeric in nature while the seventh attribute is alphanumeric in nature. For example if the distance from a potential site to a sensitive site is zero metres it implies the potential site in question is a sensitive site itself. An example of a sensitive site is a tourist site.

The third table defined in the database is called Rating and it stores a set of miscellaneous attributes. The attributes are

i Transport issues, denoted by ti in the table. Transport issues may include accessibility of the potential site.

ii Economic impact denoted by ei the table

iii Historical issues denoted by hm in the table

iv Public acceptance denoted by pn in the table v Environmental impact denoted by ec in the table

vi Sites which provide an identity to the various sites.

The first five attributes are numeric in nature and range from 0 to 1 and the sixth attribute is alphanumeric.

The fourth table defined in the database is LOCATION which spells out the location of sites. Attributes in this table are

i Longitude which spells out the longitude of a potential site.

ii Latitude which specifies the latitude of the potential site

iii Sites which provide an identity to all the sites.

All the attributes in this table are alphanumeric.

The fifth table defined in the database is called CHK and is used to hold sites selected so that the sites may be used for further selection. The table has the following attributes

i hgl which when selected for a potential site means the site has passed the hydrological and environmental test.

ii luc which when selected for a potential site implies that the site has passed the land use test

iii Rating which if selected for a potential site means the site has passed the rating(miscellaneous) test

iv Sites which provide the identity for all the potential sites.

The first three attributes are logical (Yes/No) in nature and the fourth attribute is alphanumeric.

The types of relationships that exists between records in the first table and records in the second table is one to one which means one record in first table is related to only one record in the second table.

Other relationship that were considered but not suitable here were one to many relationships where one record in one table is related to many records in the second table, many to many relationships where many records in one table are related to many records in the second table. Finally, many to one relationship where many records in one table relate to one record in the second table was examined but not found suitable for the work.

3.2.3 Interface

A menu based interface was created as a mechanism to trigger operations. The software has the following menu items CheckProcess, NextCheck, TermiateCheck, Help, File, LUC, HGC, RATING, LOCATION and CHECK. Help provides a form of documentation.

File menu provides a way of quitting from the software. ProcessCheck carries out the screening of the database based on the set criteria. Criteria are hydrological, land use, rating and location. The output from this check is the site(s) that have undergone and passed a particular criteria test. NextCheck navigates from one criteria to another eg from hydrological criteria to land use.

When checks are completed about particular set of criteria NextCheck takes execution to another criteria and ProcessCheck screens the database again based on the new criteria. TerminateCheck terminates the screening of sites at any given time. It aborts the screening process once activated.

LUC, HGC, RATING, LOCATION and CHECK menu items provide access to the LUC, HGL, Rating, Location and CHK tables respectively for the purpose of entering data. They all have two submenus called Review and Submit. Submit enables data enter through the interface to be stored permanently in the corresponding table. Review enables data already stored in the tables to be accessed.

3.2.4 Output design

The output displays results for our computation. In the work a form is used to capture the output. There are three types of outputs in the work. The first type of output displays candidates site which are site that are all suitable for sitting of solid waste management facilities with varying degrees of suitability.

A site is suitable if it possesses majority of attributes needed for the solid waste management facility. The second type of output brings out the most suitable site(s) for the sitting of solid waste facilities. This is obtained after the relaxation of setting inputs.

The output in each case will only suggest the name of the site which will not spell out the location of the site. To obtain the location of the site the Location table is queried whose output specifies the exact location of the site on the map. Location is the third output.

3.2.5 Object oriented design

The object oriented design starts with the appraisal of the real world entities that form part of the problem to be solved. It makes use of such concepts like classes, objects, polymorphism, inheritance, abstraction and encapsulation.

A class is template on which several objects are described and structured. An object is an instance of a class. There are many entity classes in a solid waste management system. A good example of such classes HGC entity-class whose data members are sites, wt (depth of water table), di (degree of infiltration), de (degree of elevation) and gq (nearness to erosion sites) Its method member is hgc-analysis(). Abstractions eliminate details and get us focus on the essentials. Polymorphism abstracts the interface of an operation leaving implementation details to subclasses. Encapsulation separates the external aspect of an object from the internal implementation details of the objects. The external aspects of an object are accessible by other objects through methods of the object while the internal implementations of those methods are hidden from the external object seeking the message.

The first step in object oriented design is the creation of Use Case models. The Use Case diagram models what happens when an actor interacts with the system. It captures the functional aspect of the system. The actors are represented as stick figures, Use Cases are shown as solid bordered ovals labeled with the name of the Use Case and the relationships are shown as arrows between actors and Use Case. The Use Case model used in the design of the integrated solid waste software is shown Fig.3.3.

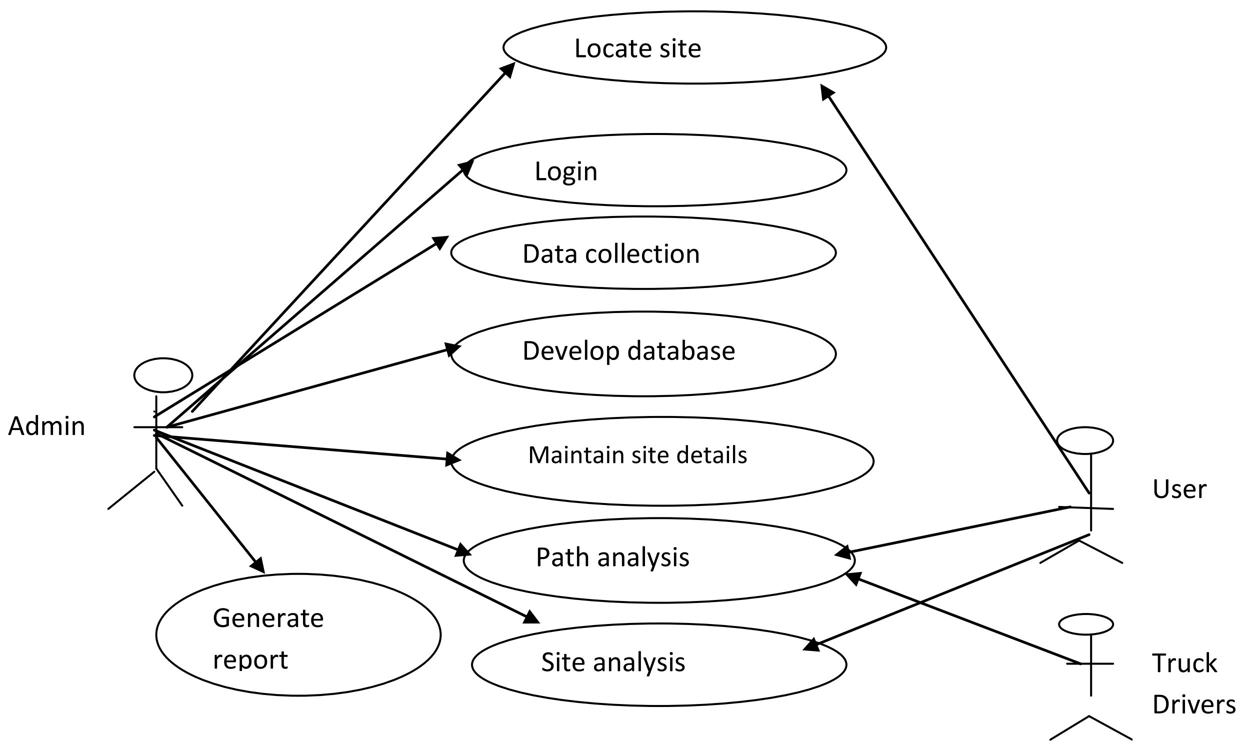

Figure 3.3: Use case Model for the Design of Solid Waste Management System

Another major step in the object oriented design that was used in the design of the integrated solid waste software system is Class diagrams which model entity classes. These entity classes become tables in the database. In the design of the software the following entity classes were identified: sites entity class, roads entity class, waste generation nodes entity class. The class diagram together with their relationship with the main module is shown in Fig.3.4.

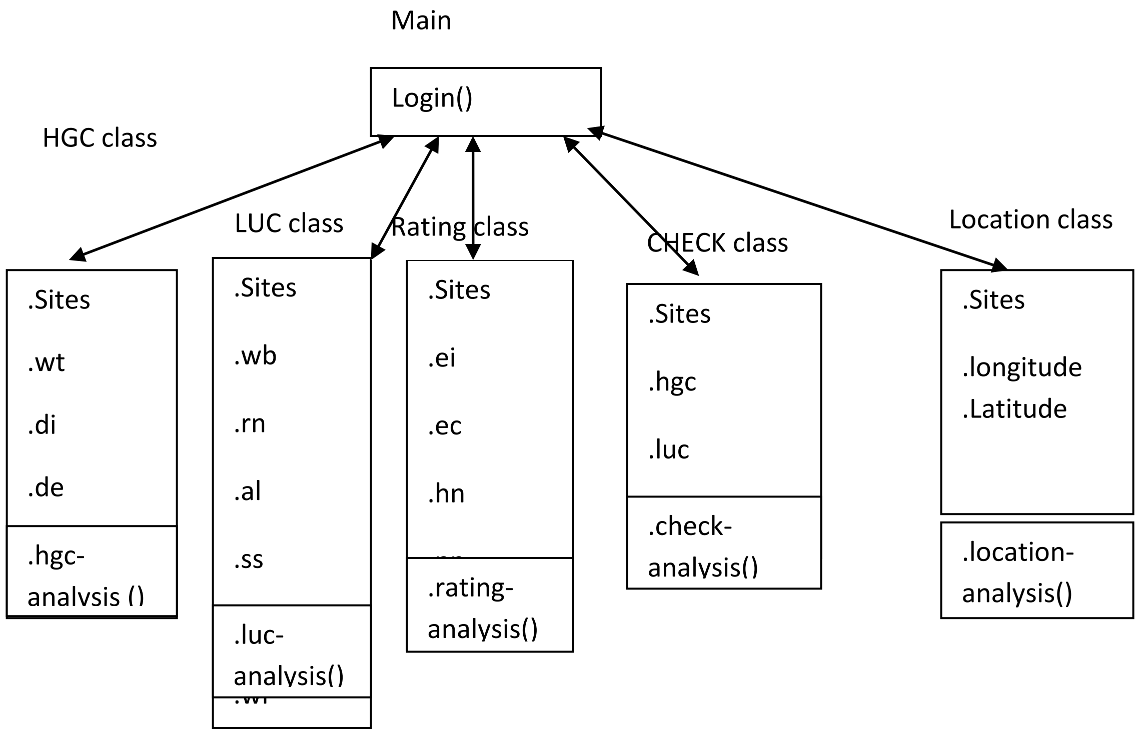

Figure 3.4: Class Diagram and Main Module

Fig. 3.4 has five entity classes namely HGC, LUC, RATING, CHECK and LOCATION. Each of these classes has two types of components. These are attributes and behavior. The attributes provide data while the behavior component provides the methods that transform the data. The HGC class has the following attributes: Sites, wt, di, de and gq standing for site name, depth of water table, degree of infiltration of the soil, degree of elevation and distance from erosion sites respectively. The only method with this class is hgc-analysis() which checks the suitability of potential sites with respect to hydrological and environmental factors.

The LUC class has the following attributes: Sites, wb, rn, al, ss, s and wl standing for site name, distance from water bodies, distance from road network, distance from arable land, distance from sensitive sites, distance from settlement and distance from waste land respectively. The only method is luc-analysis() which checks the suitability of potential sites with respect to land use factors.

The RATING class has the following attributes: Sites, ti, ei, ec, hm and pn standing for site name, transport issues, economic impact, environmental impact, historical issues and public acceptability respectively. The only method member of this class is Rating-analysis () which checks the suitability of potential sites with respect to the attributes.

CHECK class has the following attributes Sites, hgl, luc and rating standing for the site name. The remaining attributes are logical(yes/no) in nature and are used in selecting a potential landfill that passes a given test. For example a 'yes' in attribute hgl against Site B means Site B has passed the hydrological and environmental test. The only method in this class is Check-analysis() which is used in 'yes' or 'no' in a column against a potential site that passes or fails a given test .

LOCATION class has attributes Sites, longitude and latitude standing for site name, longitude and latitude of the site. Location-analysis() is the only method and it supplies the name of the as well as its location in terms of longitude and latitude.

3.2.6 Solution model

The model is about the selection of potential landfills under certain constraints. The constraints used for this model are hydrological and environmental criteria, land use criteria and rating. Rating incorporates a set of miscellaneous criteria. The model use a database with five tables defined to hold the values of the attributes. There is a table each for hydrological and environmental factors, land use factors, rating and location. There is the fifth table which is used in conjunction with the four tables to enable selection of a potential landfill. Weights are randomly assigned to attributes of the tables. Weights represent the relative importance of an attribute in the overall selection process.

We defined the selection σ operator as $\sigma\varphi(R)$

where φ is a predicate of the form $\alpha_1\emptyset\alpha_2$; α_1, α_2 are attributes and $\emptyset$ is a binary operation in the set $\{<, \geq, =, \leq, >\}$. R is a relation or a table.

We defined the join operator denoted $\bowtie$ for two relations R and S as

$$R \bowtie S = \{t \cup s: t \in R \wedge s \in S \wedge Fun(t \cup s)\} \quad 3.1$$

Where $Fun(t \cup s)$ is a predicate that is true relation $t \cup s$. For natural join the requirement imposed on this operator is that R and S must have at least one common attribute. This operator is used in joining the results of a select operation with a previously selected sites based on a common attribute, the common attributes to all tables is Sites.

We also defined the Projection operator denoted by π as $\pi a_1, \ldots, a_n(R)$,

where $a_1, \ldots, a_n$ is a set of attribute names.

This operation was used to remove unwanted columns in a relation.

The landfill selection process was carried out using the proposed model as follows

$$S_n = \pi_{Sites}(\sigma cr_i \emptyset c_i(HGL) \bowtie CHK) \bowtie \left(\sigma br_j \emptyset b_j(LUC)\right) \bowtie (\sigma dr_k \emptyset d_k(Rating) \bowtie (\pi_{Sites,x,y}(Location) \quad 3.2$$

where $S_n, n = 1, 2, \ldots,$ is the site selected,

HGL is a relation that holds hydrological and environmental attributes.

cr_i is an attribute in HGL and $c_i \geq 0$ is a corresponding constant defined and used against the attribute in the selection process. Example, for depth of water table (wt), ci must be a value in metres. LUC is a relation that holds land use attributes, br_j is an attribute in LUC and $b_j \geq 0$ is a corresponding constant defined and used against the attributes in the landfill selection process. Rating is a relation that holds a set of miscellaneous landfill selection attributes like environmental impact (ei), dr_k is an attribute in Rating and $d_k \geq 0$ is a corresponding constant defined and used against the attributes in the landfill selection process. Location is a relation that holds the location of sites, x and y stand for longitude and latitude respectively. The model for selection of landfills is also captured in Fig. 3.5. In Fig. 3.5 hydrological and environmental are first tested. Sites that passed the test are subjected to land use test. The sites that passed the land use test are further subjected to a set of miscellaneous test called rating. The sites that passed the rating test are suitable sites selected for the purpose of landfilling. Finally the location of the selected sites is obtained.

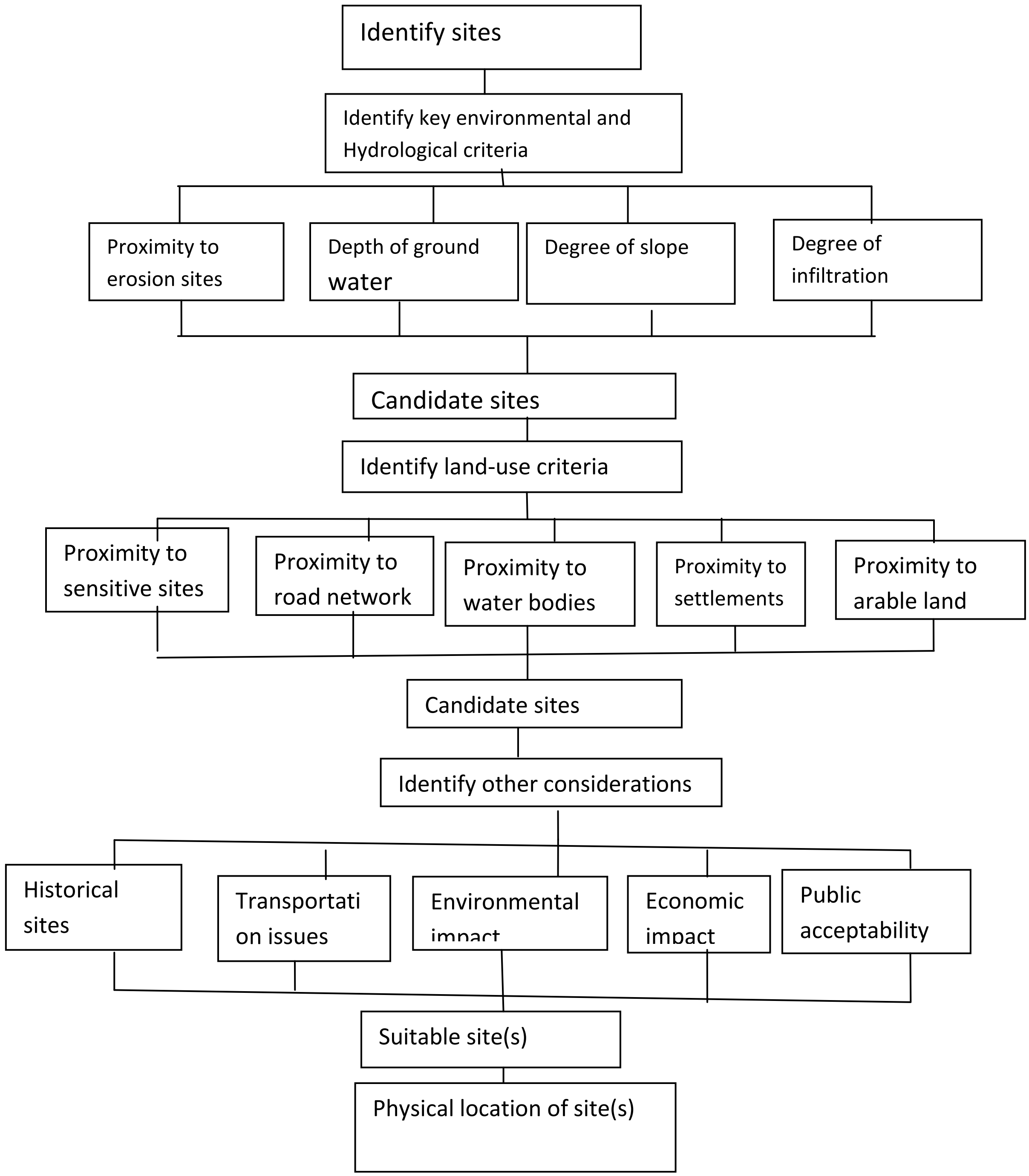

Figure 3.5: Model for Site Selection

3.2.7 Architectural specification of the software

Architectural specification leads to detailed data structure and algorithmic representation of the software. The following guidelines were used in the detailed design of the software.

i Hierarchical organization of the objects of the software

ii Modular design that is the software was logically broken down into elements that were assigned specific functions and attributes

The objects of the software are ProcessCheck which triggers the process of checking the most suitable sites for landfills. NextCheck allows the software to consider other sets of criteria for the selection of landfills. The back end of the software has a database made up of five tables four of which are used in hold hydrological and environmental attributes of sites, Land use attributes of sites, other essential considerations and locations of sites respectively.

Location table provides the location of the site on the surface of the earth. The location is given in terms of latitude and longitude. The remaining table holds the result of each analysis. The sequence of dynamic activities used in the selection of landfills using the proposed model is given in the Fig.3.6.

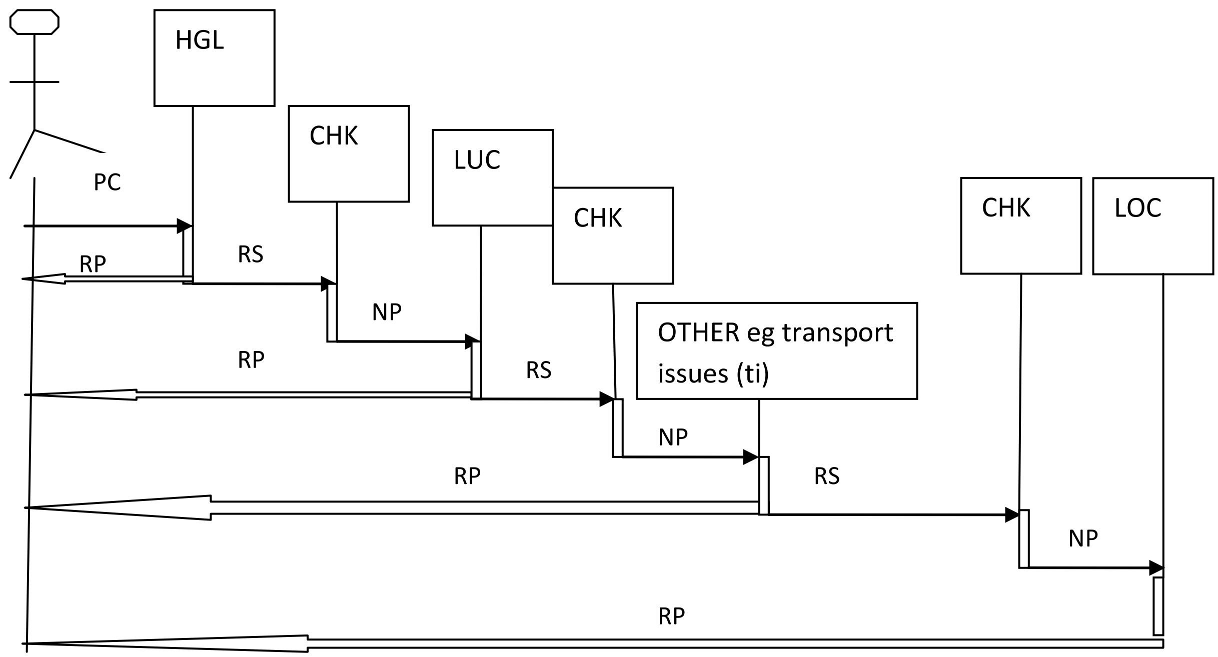

Figure 3.6: Sequence of landfills selection activities

In Fig.3.6 RP stands for the report the human operator receives from the software system, RS is the output forwarded internally by the system to be used in the next stage of analysis, PC triggers the process of selecting the landfills, NP moves from one stage of site analysis to another.

In Fig.3.6 the objects involved in the interaction are arranged horizontally and the interaction between objects represented by arrows. The thin rectangles represents the time when the object is the controlling object in the landfill selection model. An object takes control at the top of its thin rectangle and releases control to another object at the bottom of its thin rectangle.

The HGL object receives a request for site analysis from its external environment notably a user /operator to carry out analysis. It carries out the analysis and its result is put in a table called CHK. The output in CHK is a set of sites that fulfil all hydrological and environmental conditions. The user /operator further requests site analysis on Land use (LUC) factors through NextProcessCheck. Site analysis based on LUC criteria is carried out and results send to CHK. The operator further request site analysis based on a set of miscellaneous criteria called OTHER. The criteria here include economic impact, environmental impact, proximity to road network through NextProcessCheck. The analysis is done and the result sent to CHK. Sites selected here are the final sites to be used for landfilling. Finally the location(s) of the selected site(s) is obtained and result stored in CHK table. The selected sites are finally sent to users/operators.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Simulation Program

Programming translates the representation of software into a form that can be coded into a computer system for execution. The choice of a programming language for a particular project is influenced by many factors. In this work VB 6.0 is selected as a programming language based on the following factors:

i Availability of developed tools: VB comes with a lot of developed tools such as menu editors, ADODC, design toolbox which shorten the time requested to generate source code.

ii Excellent graphical user interface: VB provides excellent graphical user interface which aids both input and output design.

4.2 Hardware Requirement for the new System

The minimum hardware requirement for the new system is shown in Table 4.1

Table 4.1: Hardware Requirements for the simulation program

Item	Minimum Requirement
Processor	Pentium I, 600 MHZ
Ram	256mb
Hard Disk	1gb
Mouse	Microsoft mouse or compatible pointing device
Monitor	VGA or higher resolution screen supported by Microsoft windows

4.3 Back End

The back end of the software is a data base made of five tables created in Microsoft Access. Access is a relational database which defines its database in terms of tables. Access is chosen because of its excellent link facilities to visual basic. Five tables were created in Access and randomly populated to reflect the nature of the data for testing the software.

4.4 Testing Strategies

Testing is critical to software quality and represents the review of the specific, design and coding. In the simulation, software tests were carried out with the following objectives; Testing is a process of running a software program under development with a view of finding an error.

A good test is the one that has a high probability of locating an as-yet undiscovered error.
A successful test is the one that finds an as- yet undiscovered error.

4.4.1 Forms of testing

The software was tested using black box and white box forms of testing. Black box testing is a type of test that demonstrates that the software functionality are operational, that is, input is properly accepted, output is correctly produced and the integrity of the database is maintained.

The various functions of the software, that is, accepting of the database, screening of the sites as well as generating of reports were tested and found to be working correctly. A method of black box testing called equivalence partitioning was used to divide the inputs into classes from which test cases were derived . An equivalence class represents a set of valid or invalid states for input condition. For example condition for land use criteria are measured in distance in metres and as such no negative value is accepted. The following guidelines were used where input conditions specified a range like in the degree of infiltration under hydrological criteria: One valid and two invalid equivalent classes were defined. Boundary value analysis were used in selecting cases at the edges of the class that test cases were designed for values within a range respectively.

White box testing as a form of testing was used in testing each independent path within a module has been tested at least once, test all logical decision in the program, execute all loops at their boundaries and within their operational bounds.

The following test strategies were used in testing the simulation software:

Unit testing which focuses on the modules was used. The software comprises the following main modules; Processcheck, Nextcheck, TerminateCheck. These modules were tested against the interface, local data structure, boundary conditions, independent paths and error handling.

The modules interfaces were tested to assure proper information flows into and out of the program unit under considerations. The test guaranteed that the input values from tables were correctly accepted and correct output turned out. The local data structure assumes that data maintain their integrity during all the steps in the modules execution. Data used here were in five tables and their integrity was maintained throughout the execution of the program.

The need for an integration testing arises primarily because a module is not a stand-alone program. Integration testing is concerned with testing the modules together. The essential element in integration testing is interfacing. The two approaches of integration testing i.e big bang and incremental integration were closely studied and incremental integration was selected and used for the software testing. The big band tests the program as a whole and chaos usually results.

In incremental integration small segments of the program are added each time and errors isolated. A variation of incremental integration known as top-down integration was used. Here modules are integrated by moving downward through the control hierarchy beginning first with the main module.System Testing was also carried out to fully exercise the software. This was to ensure that the software components were fully integrated and are performing the desired functions.

4.4.2 Debugging

This occurs as a result of a successful test that is when an error or errors are uncovered in a successful test. It is a process of removing errors. The following clues were used in debugging the simulation software.

The symptom and cause of an error may be geographically remote i.e symptom may appear in one part of a software and cause located in a place that is far removed. The symptom may disappear temporally when another error is removed.
The symptom may be caused by a human factor that is not easy to locate.
The type of debugging approach used in debugging the software was backtracking where once a symptom has been detected at a site, the source code is traced backward until the site of the cause was found.

4.5 Discussion of Results

The experiment covered all the activities in selecting a landfill. This activities are ;

i Site database

ii Landfill Selection

iii Output

4.5.1 Site database

Twenty (20) sites numbered $Site_A$, $Site_B$, ...,$Site_T$ were covered and their attributes defined in five tables. The tables are named HGL, LUC, OTHER, Location and CHK. The table HGL contains all hydrological attributes of all the sites, LUC contains all land use criteria for all the sites, OTHER contains all other considerations while Location spells out the location of site. CHK contains fields that are initially empty and holds the result of the analysis.

The tables were populated randomly using data that has semblance of actual data. The nature and range of data was gotten from staff of the sanitary agencies covered in the study. The database was created using MS Access.

4.5.2 Landfill selection

Landfill selection is a complex process which in turn is broken down into smaller sets of modules. The sets of tasks used in this work are

i Module for selecting sites that meet the hydrological and environmental criteria.

ii Module for selecting sites that meet land-use criteria

iii Module for selecting sites that meet a set of miscellaneous criteria. The criteria in this group include economic impact, transport issues and environmental impact.

iv A module that displays the location of the sites selected.

The landfill was selected by running ProcessCheck which first checks the hydrological and environmental factors. Factors covered in the research are specified by the UNEPA. A site was selected from this phase based on the following criteria: Site.gq>=200 ˄ Site.wt >= 80 ˄ Site.de<=40 ˄ Site.di <=40 where gq stands for distance from erosion sites(in Metres), wt stands for depth of the water table(in Metres), di stands for degree of infiltration , de stands for degree of elevation. Degree of infiltration and degree of elevation are on a scale of 0 to 100. ˄ stands for AND. The Hydrological and environmental data, Land use data as well as the set of miscellaneous data are shown in Appendices 1, 2 and 3. The simulation code is shown in Appendix 4. Based on this after the hydrological test sites B, D, E , F, I, M, R, S were selected. The selection is shown in Table.4.2

Table 4.2 Sites Selected from Hydrological Analysis

Sites							
B	D	E	F	I	M	R	S

The above selection process can also be visualised in Fig. 4.1 and Fig. 4.2 if we split the selection conditions into two: de and di on one side and gq and wt on the other side.

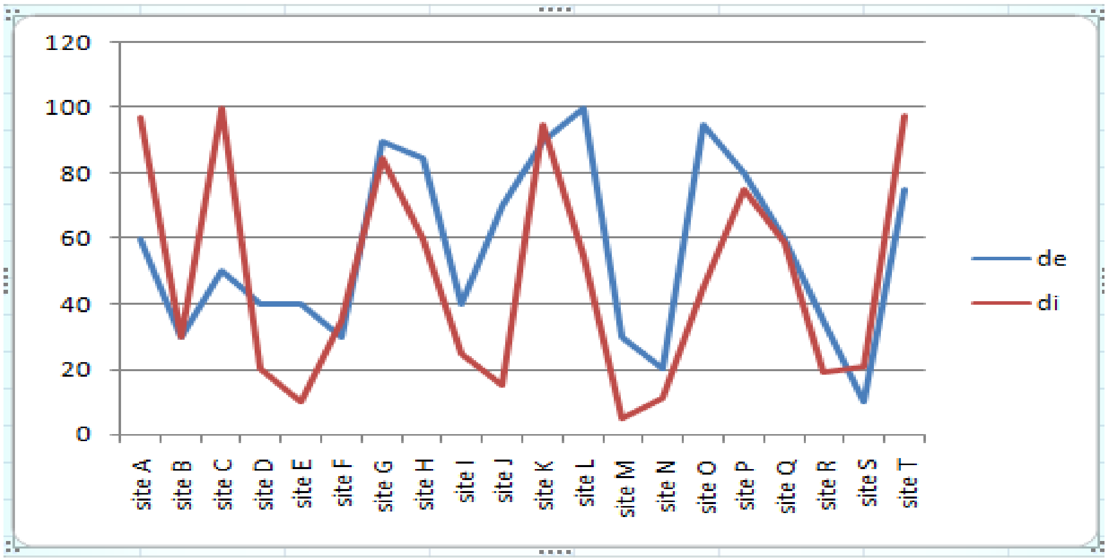

Figure 4.1: Output using only di and de

A site is selected with respect to di and de if the two curves are below or exactly on the scale of 40.

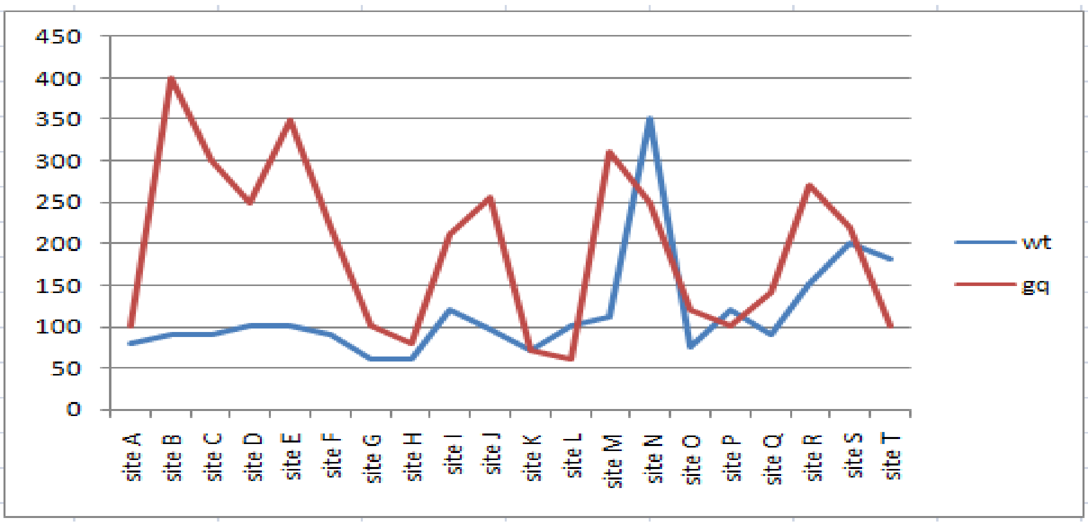

Figure 4.2: Output using only gq and wt

The separation of the separation process into figs.4.1 and 4.2 is as a result of the differences in scale among the criteria used in the selection of landfills under hydrological and environmental conditions. While fig 4.2 shows two conditions depth of water table and distance from erosion sites which are distance measured in metres fig.4.1 shows degree of infiltration and degree elevation which is placed on a scale of 1 to 100. For example, 50 in the entry for degree of infiltration are the same as 0.5. The degree of infiltration shows the permeability of the soil for the site. If the soil is porous, the degree is very high. The degree of infiltration that is higher than 40 on a scale of 100 is not accepted. This is because this may led to contamination of the underground water. A similar argument is true for the degree of elevation. If the degree is higher than 40, it is risky. The site with degree of elevation > 40 is rejected because if selected, waste can easily be drained away with rain water. A very high water table i.e distance from the water table to the surface < 80m is not accepted. This is to avoid contamination of the underground water. Similarly, a site whose distance to erosion site is < 200m is not accepted. This is because such sites are themselves prone to erosion which will have a profound effect on public health system.

The second phase of the experiment has to do with selection of landfills based on land use criteria. This selection is based on the site(s) visa-vis the following criteria all measured in distance in metres.

Water bodies (wb)

Road network (rn)

Arable land (al)

Settlements (s)

Sensitive sites (ss) and Waste land (wl)

The selection criteria is if site.wb>400 ˄ site.rn<1000 ˄ site.al>300 ˄ site.s >150 ˄ site.wl>1000 ˄ site.ss>900.

Based on the above criteria the following sites were selected: B, D, E, I and S.

The sites selected are from the sites that has earlier passed the hydrological selection criteria. The output of this phase can be seen in the Table 4.3

Table 4.3: Sites selected from Land Use Analysis

Sites				
B	D	E	I	S

The selection process can also be visualised as shown in fig.4.3

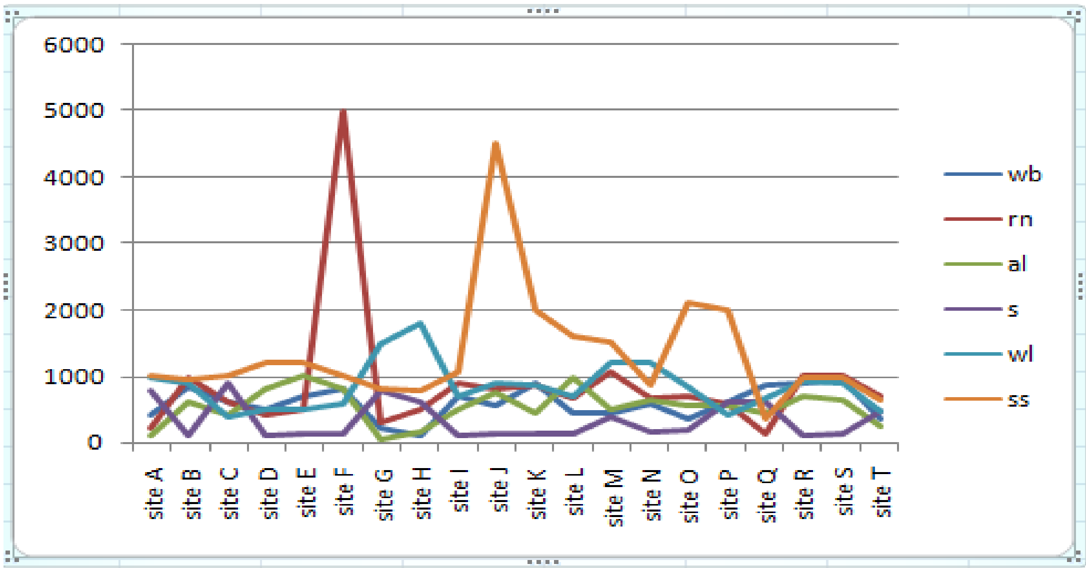

Figure 4.3: Graphical form of Land-Use Seleciton

The next phase in the site selection is to consider many other criteria not covered by both HGL and LUC factors. These set of criteria are, transport issues(ti), economic impact(ei), environmental impact(ec), historical issues(hm) and public acceptability(pn). These factors are all rated on a scale of 0 to 1. For all these factors a score of 0.4 or higher is accepted. A site is rejected if one of the criteria has a value of less than 0.4. For transport issues such a value may mean the site is inaccesible; for economic impact such a value may mean the inability of the site to create jobs for local communities or the host fees for landfill cannot be attainable. Examples of economic impact include changes in lanscape, air and surface water pollution and the effects on soil fertility. The selection criteria is

$$Site.ti >= 0.4 \wedge Site.ei >= 0.4 \wedge Site.ec >= 0.4 \wedge Site.hm >= 0.4 \wedge Site.pn >= 0.4$$

After the phase sites D, I, B and S were selected and this is shown in Table.4.4

Table 4.4: Site finally Selected

Sites			
B	D	I	S

The final selection is also shown graphically as in fig.4.4

It can be seen that a potential site that has a value of less than 0.4 is rejected.

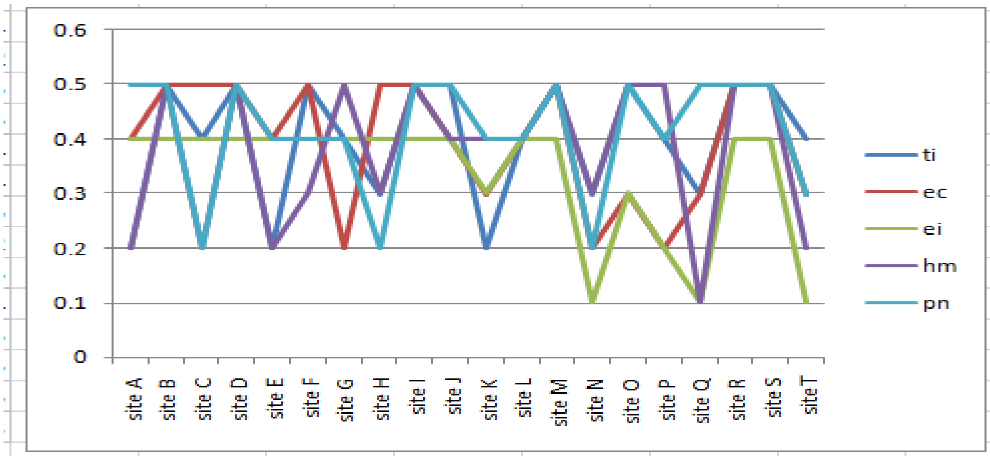

Figure 4.4 Graphical display of sites finally selected

After selecting the landfills the location database is consulted to provide their location on the surface of the earth. The location of the sites selected is shown in Table.4.5. Sites with ec, ti, ei, hm, pn below 0.4 are not selected.

Table 4.5 Location of sites

Sites	Latitude	Longitude
B	80S	70W
D	10N	15W
I	30S	30E
S	88N	66E

CHAPTER FIVE: SUMMARY, CONCLUSION AND RECOMMENDATION

5.1 Summary

In this work the components of a solid waste management system were generally studied. The study covered six cities namely Makurdi, Enugu, Calabar, Kaduna, Jalingo, and Ibadan. These towns were selected from each of the six geo-political zones of Nigeria using stratified random sampling method. The study revealed that Consideration was not given to factors determining the location of mammoth and dinosaur waste bins. In some cases waste bins are sited near flooding areas.

A waste bin capacity was also not a major consideration in some cases and the frequency of the removal of wastes was not also a major consideration in some cases. This leaves wastes to litter around the bins with the attendant problems of flies and mosquito breeding and bad odour. There was nothing like systematic truck scheduling and monitoring in all the cities covered by the research and as such huge cost is incurred by most solid waste management agencies on the operation and maintenance of garbage trucks. There was no mathematical/computer model guiding the movement of trucks in the course of waste removal.

All the towns studied implement a truck and landfill method of waste management whereby a truck leaves a garage to any of the waste bins, as directed or assigned, picks up wastes and heads straight to a landfill. Such directives are mostly ad-hoc in nature and are not scientifically coordinated. The process of picking wastes and land filling continues throughout the working hours of the day. Thereafter the truck returns to its garage. This activity is repeated five to six days a week leaving wastes to accumulate on Sundays (and Saturdays in some cases). Truck drivers in some cases use longer distances in the course of transporting wastes to landfills or travel through traffic congested routes. This is especially true for Kaduna, Enugu and Calabar towns.

In all the towns studied, waste separation is not carried out such that recyclable wastes such as paper, plastic are picked and dropped at landfills and in most cases burnt to ashes or left to litter. Waste separation by hand at household level which is the most important criterion if wealth can be generated from wastes is not carried out.

Currently, transfer stations are nearly absent in all the towns covered under the study. Transfer stations provide an avenue for temporary disposal of large amount of solid wastes which are later moved to landfills or other waste processing facilities.

In all the cities studied household wastes account for more than 75% of the total tonnage of wastes with the remaining waste coming from hospitals, offices, industries and farm settings. Waste are initially disposed using very small household bins and moved to bigger waste bins where garbage trucks can carry it to a landfill.

Path analysis was also not undertaken in any of the cities under study. Path analysis evaluates a path with minimum impedance between stations on the solid waste graph network. The path may be between an originating node and a destination node for a solid waste system. The analysis helps garbage truck drivers in effectively carrying out their activities of delivering wastes.

No clear mathematical model was identified in the cause of the analysis of the solid waste management systems. The traditional truck and landfill system is the only system used. In the truck and landfill system a truck driver leaves the garage, picks up wastes from any of the waste bins and heads straight to the landfill. No systematic optimization models are used to bring down the cost of waste management activities. The method used by the solid waste management agencies in Nigeria is a truck and landfill system with minor incineration centres .In particular the various methods of locating landfills were examined in detail and it was discovered that it site analysis was not properly carried out.

An object oriented system that selects landfills that lead to minimum pollution was designed and implemented. When the system was presented with twenty sites it was able to select the sites that lead to minimum pollution. The system is recommended for use by all solid waste management agencies. The reasons for selecting the sites was that they passed the hydrological and environmental test, land-use test and the miscellaneous test.

5.2 Conclusion

The proposed system selects landfills that lead to minimum pollution.

It requires capturing potential sites as well as their attributes and using same combining with Fuzzy reasoning and an object model to locate the landfill with the most minimum pollution.

This landfill selection method is beneficial in that it is easy to use and selects the landfills that produce minimum pollution thereby contributing to the general cleanliness of the society.

5.3 Recommendations

The work is recommended for use by sanitary agencies for the following reasons:

The process of selecting a landfill is a careful and well planned activity so as to minimise pollution; the new system provides such an approach.

The work serves as a road map for Nigeria's solid waste management agencies since it produces the site with the most minimum pollution.

The work provides a quick and efficient way of selecting Landfills thereby eliminating tedious calculations and guess work done by the solid waste management agencies of the six cites studied.

The system can be extended by combining it with a GPS to monitor illegal dumping of wastes.

The system can also be extended to monitor underground contamination by landfills.

5.4 Contributions to Knowledge

We have designed and developed a system that easily locates landfills with the most minimum pollution. The system will enhance cleanliness and contribute to the growth of our public health system.

The system checks the hydrological and environmental criteria for sitting landfills. It also checks land use criteria as well as a rates landfills using a set of miscellaneous criteria to select the landfill(s) with the most minimum pollution.

The system is intended to eliminate the manual/adhoc method currently employed by the solid waste management agencies in Nigeria.

We have designed and implemented the system which combines a geo-database model, Fuzzy model and an object model to select landfills that led to minimum pollution.

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APPENDIX 1: HYDROLOGICAL AND ENVIRONMENTAL DATA

Sites	Wt	De	Gq	Di
A	80	60	100	97
B	90	30	400	30
C	90	50	300	100
D	100	40	250	20
E	100	40	350	10
F	90	30	220	35
G	60	90	100	85
H	60	85	80	60
I	120	40	210	25
J	95	70	255	15
K	70	90	70	95
L	100	100	60	55
M	110	30	310	5
N	350	20	250	11
O	75	95	120	45
P	120	80	100	75
Q	90	60	140	59
R	150	35	270	19
S	200	10	220	21
T	180	75	100	98

APPENDIX 2: LAND -USE DATA

Sites	Wb	Rn	Al	S	Wl	Ss
A	400	200	100	800	1000	1000
B	850	970	600	105	908	960
C	600	600	400	900	400	1000
D	500	400	800	100	500	1200
E	700	500	1000	120	500	1200
F	800	5000	800	140	600	1000
G	200	300	50	800	1500	800
H	100	500	150	600	1800	780
I	700	900	500	100	700	1050
J	550	800	750	120	900	4500
K	900	850	450	130	870	2000
L	430	650	970	120	695	1600
M	450	1050	500	400	1200	1500
N	570	650	650	170	1200	850
O	350	700	550	200	850	2100
P	600	560	546	620	430	2005
Q	870	120	432	609	679	356
R	900	1005	700	110	920	065
S	950	995	650	125	905	970
T	350	680	240	460	470	636

APPENDIX 3: MISCELLANEOUS DATA

Sites	Ti	Ec	Ei	Hm	pn
A	0.2	0.4	0.4	0.2	0.5
B	0.5	0.5	0.4	0.5	0.5
C	0.4	0.5	0.4	0.2	0.2
D	0.5	0.5	0.4	0.5	0.5
E	0.2	0.4	0.4	0.2	0.4
F	0.5	0.5	0.4	0.3	0.4
G	0.4	0.2	0.4	0.5	0.4
H	0.3	0.5	0.4	0.3	0.2
I	0.5	0.5	0.4	0.5	0.5
J	0.5	0.4	0.4	0.4	0.5
K	0.2	0.3	0.3	0.4	0.4
L	0.4	0.4	0.4	0.4	0.4
M	0.5	0.5	0.4	0.5	0.5
N	0.3	0.2	0.1	0.3	0.2
O	0.5	0.3	0.3	0.5	0.5
P	0.4	0.2	0.2	0.5	0.4
Q	0.3	0.3	0.1	0.1	0.5
R	0.5	0.5	0.4	0.5	0.5
S	0.5	0.5	0.4	0.5	0.5
T	0.4	0.3	0.1	0.2	0.3

APPENDIX 4: PROGRAM LISTING

```
Option Explicit

Public LoginSucceeded As Boolean

Private Sub cmdCancel_Click()

    'set the global var to false

    'to denote a failed login

    LoginSucceeded = False

    Me.Hide

End Sub

Private Sub cmdOk_Click()

frmLogin.Show

txtPassword.Visible = True

lblLabels(1).Visible = True

Me.Hide

End Sub

Private Sub Command1_Click()

On Error Resume Next

Dim foundflag As Boolean

Data2.Recordset.MoveLast

Data2.Recordset.MoveFirst
```

```
Do While Not Data2.Recordset.EOF
    If Data2.Recordset.Fields("Password") = txtPassword.Text Then
    foundflag = True
    lblLabels(2).Visible = True
    lblLabels(3).Visible = True
    lblLabels(0).Visible = False
    lblLabels(1).Visible = False
    Command2.Visible = True
    Text1.Visible = True
    Text2.Visible = True
    Command1.Visible = False
    txtPassword.Visible = False
    Data2.Recordset.Delete
If Not Data2.Recordset.EOF Then
Data2.Recordset.MoveNext
ElseIf Not Data2.Recordset.BOF Then
Data2.Recordset.MovePrevious
Else
MsgBox "This is the last record in the table"
Exit Sub
```

```
End If
    Data1.Recordset.AddNew
    Exit Sub
    Else
      Data2.Recordset.MoveNext
    foundflag = False
    End If
Loop
If foundflag = False Then
MsgBox "The Record is not found"
Exit Sub
End If
End Sub
Private Sub Command2_Click()
On Error Resume Next
Data1.Recordset.AddNew
MsgBox "Your Password and User Name has been Changed Successfully"
cmdOK.Enabled = True
cmdCancel.Enabled = True
Command2.Visible = False
```

```
Text1.Visible = False

Text2.Visible = False

txtPassword.Visible = False

lblLabels(1).Visible = False

lblLabels(2).Visible = False

lblLabels(3).Visible = False

End Sub

Private Sub Form_Load()

Data1.DatabaseName = App.Path & "\Amodu.mdb"

Data2.DatabaseName = App.Path & "\Amodu.mdb"

End Sub

Private Sub Timer1_Timer()

ProgressBar1.Value = ProgressBar1.Value + 50

If ProgressBar1.Value = ProgressBar1.Max Then

On Error Resume Next

Data2.Recordset.AddNew

Data1.Recordset.AddNew

ProgressBar1.Visible = False

Timer1.Enabled = False

ProgressBar1.Value = 0
```

```
End If
End Sub
Public conn As New ADODB.Connection
Public trs As New ADODB.Recordset
Public Function openData()
    conn.Provider = "Microsoft jet 4.0 ole db provider"
    conn.Open App.Path & "\Landfills.mdb"
End Function
Public Sub Loadlv(lv As ListView, sql As String)
    Dim rs As New ADODB.Recordset
    rs.Open sql, conn
    Dim li As ListItem
    Dim lvw As ListView
    Set lvw = lv
    If (rs.EOF = True And rs.BOF) = True Then Exit Sub
        lvw.ListItems.Clear
        Do While Not rs.EOF
            Set li = lvw.ListItems.Add
            li.Text = rs!us
            rs.MoveNext
```

```
        Loop
    Set rs = Nothing
End Sub
Public Sub Ldlv(lv As ListView, sql As String)
    Dim rs As New ADODB.Recordset
    rs.Open sql, conn
    Dim li As ListItem
    Dim lvw As ListView
    Set lvw = lv
    If (rs.EOF = True And rs.BOF) = True Then Exit Sub
      lvw.ListItems.Clear
      Do While Not rs.EOF
        Set li = lvw.ListItems.Add
        li.Text = rs!us
        li.SubItems(1) = rs!gt
        li.SubItems(2) = rs!gc
        rs.MoveNext
        Loop
    Set rs = Nothing
End Sub
```

```
Dim Sites As String, di As String

Private Sub Ex_Click()

End

End Sub

Private Sub Hom_Click()

frmAbout.Show

Me.Hide

End Sub

Private Sub Nc_Click()

Form2.Show

 Frame2.Visible = True

Fl.Enabled = True

Sb.Enabled = True

Me.Hide

End Sub

Private Sub Pr_Click()

Form6.Show

Me.Hide

End Sub

Private Sub Sb_Click()
```

```
Dim wt As Single, De As Single, gq As Single

If IsNumeric(Text1.Text) Then

MsgBox "Invalid Sites entered, check Sites Cannot be numeric"

Exit Sub

End If

If IsNumeric(Text3.Text) Then

MsgBox "Invalid di entered, check di Cannot be numeric"

Exit Sub

End If

If IsNumeric(Text2.Text) Then

If IsNumeric(Text4.Text) Then

If IsNumeric(Text5.Text) Then

If Text1.Text <> "" Or Text2.Text <> "" Or Text3.Text <> "" Or Text4.Text <> "" Or Text5.Text <> "" Then

On Error Resume Next

Adodc1.Recordset.AddNew

Else

MsgBox "One or some entries are missing, check and try again"

Exit Sub

End If
```

```
Else

MsgBox "Invalid wt entered, check wt must be numeric "

Exit Sub

End If

Else

MsgBox "Invalid de entered, check de must be numeric"

Exit Sub

End If

Else

MsgBox "Invalid gq entered, check gq must be numeric"

Exit Sub

End If

End Sub

Private Sub Su_Click()

On Error Resume Next

Adodc1.Recordset.AddNew

MsgBox "The Update has been done successfully"

Sb.Enabled = True

Se.Enabled = True

Nc.Enabled = True
```

```
Fl.Enabled = True
Pr.Enabled = True
End Sub
Private Sub Timer1_Timer()
Label7.Caption = "Hydrological Factor"
 Label7.Left = Label7.Left + 30
If Label7.Left > 4000 Then
Label7.Left = 220
End If
End Sub
Private Sub Se_Click()
Timer3.Enabled = True
End Sub
Private Sub Timer2_Timer()
ProgressBar1.Value = ProgressBar1.Value + 50
If ProgressBar1.Value = ProgressBar1.Max Then
On Error Resume Next
Adodc1.Recordset.AddNew
ProgressBar1.Visible = False
Timer2.Enabled = False
```

```
ProgressBar1.Value = 0

End If

End Sub

Private Sub Data3_Validate(Action As Integer, Save As Integer)

End Sub

Private Sub Ex_Click()

End

End Sub

Private Sub Nc_Click()

  Frame2.Visible = True

Fi.Enabled = True

Sb.Enabled = True

Form4.Show

Me.Hide

End Sub

Private Sub Pc_Click()

Timer3.Enabled = True

End Sub

Private Sub Pr_Click()

Form8.Show
```

```
Me.Hide

End Sub

Private Sub Sa_Click()

On Error Resume Next

Data4.Recordset.AddNew

Nc.Enabled = True

End Sub

Private Sub Sb_Click()

If IsNumeric(Text1.Text) Then

MsgBox "Invalid Sites entered, check Sites Cannot be numeric"

Exit Sub

End If

If Text1.Text <> "" Or Combo1.Text <> "" Or Combo2.Text <> "" Or Combo3.Text <> ""
Or Combo4.Text <> "" Then

On Error Resume Next

Adodc1.Recordset.AddNew

Else

MsgBox "One or More entries have not been entered or selected, check and try again"

Exit Sub

End If
```

```
End Sub

Private Sub Timer1_Timer()

Label7.Caption = "Rating"

 Label7.Left = Label7.Left + 30

If Label7.Left > 4000 Then

Label7.Left = 220

End If

End Sub

Private Sub Timer2_Timer()

ProgressBar1.Value = ProgressBar1.Value + 50

If ProgressBar1.Value = ProgressBar1.Max Then

On Error Resume Next

Adodc1.Recordset.AddNew

ProgressBar1.Visible = False

Timer2.Enabled = False

ProgressBar1.Value = 0

End If

End Sub

Private Sub Ex_Click()

End
```

```
End Sub

Private Sub Hom_Click()

frmAbout.Show

Me.Hide

End Sub

Private Sub Nc_Click()

Form10.Show

Frame2.Visible = True

Fi.Enabled = True

Su.Enabled = True

Me.Hide

End Sub

Private Sub Pc_Click()

Timer3.Enabled = True

End Sub

Private Sub Pr_Click()

Form7.Show

Me.Hide

End Sub

Private Sub Su_Click()
```

```
If IsNumeric(Text1.Text) Then

MsgBox "Invalid Sites entered, check Sites Cannot be numeric"

Exit Sub

End If

If IsNumeric(Text5.Text) Then

If IsNumeric(Text6.Text) Then

If IsNumeric(Text7.Text) Then

If IsNumeric(Text2.Text) Then

If IsNumeric(Text3.Text) Then

If IsNumeric(Text4.Text) Then

If Text1.Text <> "" Or Text2.Text <> "" Or Text3.Text <> "" Or Text4.Text <> "" Or Text5.Text <> "" Or Text6.Text <> "" Or Text7.Text <> "" Then

On Error Resume Next

Adodc1.Recordset.AddNew

Else

MsgBox "One or some entries are missing, check and try again"

Exit Sub

End If

Else

MsgBox "Invalid al entered, check al must be numeric "
```

```
Exit Sub

End If

Else

MsgBox "Invalid m entered, check m must be numeric"

Exit Sub

End If

Else

MsgBox "Invalid wb entered, check wb must be numeric"

Exit Sub

End If

Else

MsgBox "Invalid ss entered, check ss must be numeric "

Exit Sub

End If

Else

MsgBox "Invalid wl entered, check wl must be numeric"

Exit Sub

End If

Else

MsgBox "Invalid s entered, check s must be numeric"
```

```
Exit Sub

End If

End Sub

Private Sub Timer1_Timer()

ProgressBar1.Value = ProgressBar1.Value + 50

If ProgressBar1.Value = ProgressBar1.Max Then

On Error Resume Next

Adodc1.Recordset.AddNew

ProgressBar1.Visible = False

Timer1.Enabled = False

ProgressBar1.Value = 0

End If

End Sub

Private Sub Ex_Click()

End

End Sub

Private Sub Hom_Click()

frmAbout.Show

Me.Hide

End Sub
```

```
Private Sub Nc_Click()
On Error Resume Next
Frame1.Visible = True
    Frame2.Visible = True
    Fi.Enabled = True
    Sb.Enabled = True
  Pc.Enabled = True
    Form5.Show
    Me.Hide
End Sub
Private Sub Pr_Click()
Form9.Show
Me.Hide
End Sub
Private Sub Sb_Click()
If IsNumeric(Text1.Text) Then
MsgBox "Invalid Sites entered, check Sites Cannot be numeric"
Exit Sub
End If
If IsNumeric(Text2.Text) Then
```

```
MsgBox "Invalid Lat entered, check Lat Cannot be numeric"
Exit Sub
End If
If IsNumeric(Text3.Text) Then
MsgBox "Invalid Lon entered, check Lon Cannot be numeric"
Exit Sub
End If
If Text1.Text <> "" Or Text2.Text <> "" Or Text3.Text <> "" Then
On Error Resume Next
Adodc1.Recordset.AddNew
Else
MsgBox "One or More enteries have not been entered, check and try again"
Exit Sub
End If
End Sub
Private Sub Timer1_Timer()
Label4.Caption = "Location"
 Label4.Left = Label4.Left + 30
If Label4.Left > 4000 Then
Label4.Left = 220
```

```
End If
End Sub
Private Sub Timer2_Timer()
ProgressBar1.Value = ProgressBar1.Value + 50
If ProgressBar1.Value = ProgressBar1.Max Then
On Error Resume Next
Adodc1.Recordset.AddNew
ProgressBar1.Visible = False
Timer2.Enabled = False
ProgressBar1.Value = 0
End If
End Sub
Private Sub execProc()
   Timer1.Enabled = True
End Sub
Private Sub cmdTerminate_Click()
   Timer1.Enabled = False
   End Sub
Private Sub Form_Load()
   a = 1
```

```
    openData
End Sub
Private Sub Form_Unload(Cancel As Integer)
    conn.Execute ("update chk set hgc=false,luc=false,rating=false")
End Sub
Private Sub H_Click()
Form1.Show
Me.Hide
End Sub
Private Sub Lo_Click()
Form4.Show
Me.Hide
End Sub
Private Sub LU_Click()
Form2.Show
Me.Hide
End Sub
Private Sub mnuAbout_Click()
    frmAbout.Show
End Sub
```

```
Private Sub mnuFileExit_Click()
    End
End Sub
Private Sub mnuIndex_Click()
frmIndex.Show
End Sub
Private Sub Ra_Click()
Form10.Show
Me.Hide
End Sub
Private Sub Timer1_Timer()
    ProgressBar1.Value = ProgressBar1.Value + 1
    If ProgressBar1.Value = ProgressBar1.Max Then ProgressBar1.Value = 0: Timer1.Enabled = False: MsgBox "Done", vbInformation, Me.Caption: CheckData: Exit Sub
End Sub
Dim a As Integer
Private Sub Ck_Click()
Form5.Show
Me.Hide
End Sub
```

```
Private Sub cmdInformation_Click()
    If a = 1 Then
    frmHydrology.Caption = "Land Fills [Land Use Criteria]"
    a = 2
    Exit Sub
    ElseIf a = 2 Then
    frmHydrology.Caption = "Land Fills [Rating]"
    a = 3
    Exit Sub
    ElseIf a = 3 Then
    frmHydrology.Caption = "Land Fills [Location]"
    a = 4
    Exit Sub
    End If
End Sub
Private Sub cmdProcesscheck_Click()
    execProc
   ' CheckData
    End Sub
Private Function CheckData()
```

```
If a = 1 Then
    trs.Open ("Select hgc.sites from hgc where hgc.wt >=80 and hgc.de<=40 and hgc.di <=40 and hgc.gq>=200"), conn
    Do Until trs.EOF
    conn.Execute ("update chk set hgc='1' where chk.sites='" & trs!Sites & "'")
    trs.MoveNext
    Loop
    Set trs = Nothing
    Loadlv Lview1, "Select chk.sites as us from chk where hgc= true "
ElseIf a = 2 Then
    trs.Open ("select sites from luc where wb>400 and rn<1000 and al>300 and s>150 and wl>1000 and ss>900"), conn
    Do Until trs.EOF
    conn.Execute ("update chk set luc='1' where chk.sites='" & trs!Sites & "'")
    trs.MoveNext
    Loop
    Set trs = Nothing
    Loadlv Lview1, "select sites as us from chk where luc =true and hgc=true"
ElseIf a = 3 Then
    trs.Open ("select sites from rating where ti >=.4 and ec >=.4 and ei>=.4and pn>=.4 and hm>=.4"), conn
```

```
Do Until trs.EOF
conn.Execute ("update chk set rating='1' where chk.sites='" & trs!Sites & "'")
trs.MoveNext
Loop
Set trs = Nothing
Loadlv Lview1, "select sites as us from chk where luc=true and rating=true and hgc=true "
ElseIf a = 4 Then
Lview1.Visible = False
ListView1.Visible = True
Ldlv ListView1, "select location.sites as us,location.lat as gt,location.lon as gc from Location inner join chk on location.sites=chk.sites where chk.luc=true and chk.hgc=true and chk.rating=true"
End If
End Function
Private Sub execProc()
Timer1.Enabled = True
End Sub
Private Sub cmdTerminate_Click()
Timer1.Enabled = False
End Sub
```

```
Private Sub Form_Load()
    a = 1
    openData
End Sub


Private Sub Form_Unload(Cancel As Integer)
    conn.Execute ("update chk set hgc=false,luc=false,rating=false")
End Sub
Private Sub H_Click()
Form1.Show
Me.Hide
End Sub
Private Sub Lo_Click()
            Form4.Show
            Me.Hide
End Sub
Private Sub LU_Click()
Form2.Show
Me.Hide
End Sub
```

```
Private Sub mnuAbout_Click()

   frmAbout.Show

End Sub

Private Sub mnuFileExit_Click()

   End

End Sub

Private Sub mnuIndex_Click()

frmIndex.Show

End Sub

Private Sub Ra_Click()

Form10.Show

Me.Hide

End Sub

Private Sub Timer1_Timer()ProgressBar1.Value = ProgressBar1.Value + 1 If ProgressBar1.Value = ProgressBar1.Max Then ProgressBar1.Value = 0: Timer1.Enabled = False: MsgBox "Done", vbInformation, Me.Caption: CheckData: Exit Sub

End Sub
```