METHODOLOGY

4.1 OVERVIEW
The selection of municipal solid waste disposal site involves a multi-disciplinary approach and a broad spectrum of considerations. The selection of waste disposal sites for Hyderabad city involves primarily the selection of preliminary criteria to be considered for site selection followed by grouping of these criteria into exclusionary and non-exclusionary or inclusionary criteria. Exclusionary criteria involve those considerations, which are of stringent nature. The factors of exclusionary directly decides the suitability by YES or NO. If a selected site does not satisfy these considerations, it has to be excluded. Non-exclusionary criteria include those considerations that although not as stringent, are nevertheless important. Non-Exclusionary factors need ranking, and each individual factor will have the weightage of suitability. The non-exclusionary weightage will be assigned only to the locations left after the exclusionary screening. Analytical Hierarchy Process (AHP) gives the facilitated way in decision-making in which, the factors are sorted according to their relation and importance to the site of dumping which is called hierarchy of importance. To derive the decision factors of exclusionary and non-exclusionary and to apply the AHP, the baseline digital database is necessary and this database is created on GIS platform.

In the process of site selection, broadly two types of database are generated, which are discussed in the following sections. These two types of database are spatial database and non-spatial / attribute database. The spatial data comprises of all the thematic and topographic maps viz., land use/land cover, geomorphology, drainage, watershed, physiography, base details, slope, geology, soil etc. and the other derivative maps like groundwater potential, infiltration rate, groundwater prospects, groundwater table, etc. The non-spatial or attribute data is composed of population details, solid waste generation rates, groundwater quality, soil type and air quality data. In this chapter, the steps involved in deriving all these data products, the sources of data acquisition and the ways of transforming these data products suitable to GIS software are described.
4.2 GIS DATA SOURCES

A heightened awareness of environmental problems developed over the past few decades has spurred a need for reliable geospatial data to enable better understanding of environmental processes and their impacts. Environmental models have also undergone changes and these have created new requirements for geospatial data. In view of critical role, data plays in any kind of spatial modeling; emphasis is given to new information gathering initiations for remotely sensed data and to advancements in integrating data for different sources with GIS.

GIS is a powerful tool for environmental data analysis and planning. It stores spatial information (data) in a digital mapping environment. A digital base map can be overlaid with data or other layers of information onto a map in order to view spatial information and relationships. GIS allows better viewing and understanding of physical features and the relationships that influence in a given critical environmental condition.

GIS and environmental models function with a broad spectrum of geospatial data that are used for spatial analysis and modeling of environmental related problems at different scales. These data generally come in different formats and from various sources and measurements. The examination and organization of data into a useful form produces information content, which is compatible to GIS, which enables appropriate analysis and modeling of urban environment.

GIS is an information management system capable of providing spatial analysis tools for storing, retrieving, and manipulating georeferenced computerized maps. GIS is widely used in various research fields including landfill siting (Jehng-Jung Kao et al, 1996). Lindquist (1991) stated four advantages of applying a GIS to assist landfill siting: (1) an objective zone exclusion process solely according to a set of provided screening criteria; (2) capability of handling a large amount of complex geographical data; (3) flexibility for implementing “what-if” data analysis; and (4) visualization of results and graphical presentation.
In the present study three different sources are used to collect the required data. The three sources are remote sensing satellite data from National Remote Sensing Agency (NRSA), Survey of India (SOI) toposheets and related Government and private agencies for existing data products. In transforming this raw data to data compatible to GIS, care is taken for appropriate level of data precision and accuracy. The data types, important features and corresponding data sources used in the present study are listed in Table 4.1.

<table>
<thead>
<tr>
<th>S No.</th>
<th>Data Type</th>
<th>Features</th>
<th>Source of acquisition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Thematic Data</td>
<td>Land use / Land cover</td>
<td>Built-up land, agricultural land, Water bodies, BSA, land with scrub, land without scrub, single and double crop, plantations etc.</td>
</tr>
<tr>
<td>2</td>
<td>Geomorphology</td>
<td>Pediplain-Inselberg complex, Pediplain with moderate weathering, Pediplain with shallow weathering, Residual hill, Pediment, Alluvial plain, Valley fill etc.</td>
<td>Satellite data + SOI Toposheet</td>
</tr>
<tr>
<td>3</td>
<td>Geology</td>
<td>Granite, Pegmatite, AAG, AMG, AT etc.</td>
<td>Hyderabad quadrangle map from Geological Survey of India, Hyderabad</td>
</tr>
<tr>
<td>4</td>
<td>Structures</td>
<td>Conformed lineaments, Inferred lineaments, faults etc.</td>
<td>Hyderabad quadrangle map and Satellite data</td>
</tr>
<tr>
<td>5</td>
<td>Soil</td>
<td>Clay, gravelly clay, gravelly loamy etc.</td>
<td>Satellite data + Land use and Soil Survey Department</td>
</tr>
</tbody>
</table>

### Table 4.1 Data Type, Important Features and Sources of Acquisition

<table>
<thead>
<tr>
<th>S No.</th>
<th>Data Type</th>
<th>Features</th>
<th>Source of acquisition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Topographic Data</td>
<td>Base map</td>
<td>Rivers/water bodies, major roads, railways.</td>
</tr>
<tr>
<td>2</td>
<td>Drainage map</td>
<td>Drainage pattern, rivers, tanks</td>
<td>Toposheets of Survey of India</td>
</tr>
<tr>
<td></td>
<td>Data derived from other thematic and topographic maps</td>
<td></td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>------------------------------------------------------</td>
<td>--</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Transportation Network map</td>
<td>Major settlements, major roads and minor roads</td>
<td>Survey of India Toposheet</td>
</tr>
<tr>
<td>4</td>
<td>Watershed map</td>
<td>Watersheds, drainage pattern, major water bodies</td>
<td>Survey of India Toposheet</td>
</tr>
<tr>
<td>5</td>
<td>Slope map</td>
<td>Slope classes 1 to 6</td>
<td>Survey of India Toposheet</td>
</tr>
</tbody>
</table>

**III**

<table>
<thead>
<tr>
<th></th>
<th>Data derived from other thematic and topographic maps</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Physiography</td>
<td>Hills, Undulating land and plains</td>
</tr>
<tr>
<td>2</td>
<td>GW Potential map</td>
<td>Classification into high, medium and low based on yield/availability</td>
</tr>
<tr>
<td>3</td>
<td>GW table map</td>
<td>High, medium and low zones depending on depth of water table</td>
</tr>
<tr>
<td>4</td>
<td>Infiltration rate map</td>
<td>High, medium and low zones depending on infiltration rate</td>
</tr>
</tbody>
</table>

**IV**

<table>
<thead>
<tr>
<th></th>
<th>Collateral Data</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Demographic data</td>
<td>Population density</td>
</tr>
<tr>
<td>2</td>
<td>Rainfall Data</td>
<td>Rainfall</td>
</tr>
<tr>
<td>3</td>
<td>Existing ground water quality data</td>
<td>Ground water quality</td>
</tr>
<tr>
<td>4</td>
<td>Existing Air quality data</td>
<td>Air quality</td>
</tr>
</tbody>
</table>
4.3 GIS DATA TYPES
Basically all the GIS data used in this study are classified as
- Topographical data
- Thematic data
- Collateral data
The topographical and thematic data are classified as spatial data and the collateral data as attribute data. The details of these types of data products are discussed below.

4.4 SPATIAL DATA
The spatial data consists of topographic, thematic and other derivative maps derived from satellite sensing system and SOI toposheets. The satellite sensors are Panchromatic (PAN) and LISS-III (Linear Imaging Self Scanner) sensors of IRS-ID satellite. SOI toposheet series are 56K/1 to 56K/16 on 1:50,000 scale. The step-by-step procedure for preparing the spatial data for the entire study area is given in Fig. 4.1 and is discussed below.

Step 1: Satellite data processing using image-processing software like ERDAS (Earth Resource Development Application System) and EASI/PACE (EASI - Environmental Analysis and Scientific Interface, PACE - Programming language) and hardcopy generation
Step 2: Generation of thematic maps viz., land use / land cover, geomorphology, geology, groundwater prospects etc by visual interpretation of satellite imagery and SOI toposheets.
Step 3: Generation of topographical maps showing physical characteristics of the study area. The topographical maps extracted from SOI toposheets are base, road network, drainage, watershed, slope and physiography.
Step 4: Generation of maps derived from other thematic and topographic maps.
Step 5: Scanning and digitization of the thematic, topographic and other derivative maps
Step 6: Digital spatial database generation using ARC/INFO and Arc View GIS software

4.4.1 Satellite Data Processing
The second generation operational Indian Remote Sensing IRS-ID satellite was launched in the year 1998 by the indigenously developed Polar Satellite Launch Vehicle (PSLV) from Sriharikota, India. This satellite is placed in a near circular, sun-synchronous, near polar
orbit with nominal inclination of 98°53' at a mean attitude of 780 Km. There are three sensors on-board this satellite, namely 1) Panchromatic Camera (PAN) 2) Linear Imaging Self Scanning Sensor (LISS III) 3) Wide Field Sensor (WiFS) (Anji Reddy, 2001).

In this study, digital remote sensing data of LISS III and PAN of IRS ID obtained from NRSA is used. Therefore, it is more appropriate to give the sensor characteristics of LISS III and PAN (Table 4.2). Base map on 1:50,000 scale obtained from SOI toposheets covering the entire study area is used to extract the Ground Control Points (GCPs) and to demarcate the boundary of study area on imagery. This information is then used for image registration of LISS III and PAN digitally using ERDAS image processing software.

<table>
<thead>
<tr>
<th>Sensor Characteristics</th>
<th>Sensor Characteristics of IRS ID (LISS III and PAN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spatial Resolution</td>
<td>LISS III 23.5 m</td>
</tr>
<tr>
<td>Spectral Resolution</td>
<td>LISS III 4</td>
</tr>
<tr>
<td>Radiometric Resolution</td>
<td>LISS III 6</td>
</tr>
<tr>
<td>Swath width</td>
<td>LISS III 127-141</td>
</tr>
</tbody>
</table>

4.4.1.1 Geo-coding and Geo-referencing

The following standard techniques employing ERDAS Image Processing software have been adopted for Geo-referencing of LISS III and PAN data covering the study area. Toposheets covering the entire study area on 1:50,000 scale are scanned and raster file is created. These are further geo-referenced based on the longitudinal & latitudinal coordinates. After geo-referencing all the maps are edge-matched and a digital mosaic is prepared which depicts the continuity of the study area.

The LISS III data obtained from NRSA is processed for initial corrections like drop outs, stripping and earth rotations. Sufficient number of well-distributed ground control points are selected both on the toposheet and corresponding imagery. Care is taken to satisfy the condition on density of GCPs for image registration. Geo-referencing is carried out using
ERDAS image processing software. The geo-referenced image is further mosaicked and then feature matching is carried out. Similar procedure is applied for PAN data. At the end of this process the digital data free from all distortions is available for digital image enhancement and thematic map preparation with the help of visual image analysis techniques.

4.4.1.2 Digital Image Enhancement of LISS III data
Image enhancement procedures are applied to image data in order to more effectively display or record the data for subsequent visual interpretation. Image enhancement deals with the techniques for increasing the visual distinctions between features in a scene (Lillesand and Keifer, 2000). The goal of spectral enhancement is to make certain features more visible in an image by bringing out more contrast. Initial display of LISS III data through ERDAS software revealed that the features like minor roads, streams and river are not clear / visible as the contrast of the image is very dull because the raw data values fall within a narrow range. Therefore, an attempt is made to apply linear contrast stretch technique in order to improve the contrast of the image, which can be capable of expanding the dynamic range of radiometric resolution of LISS III digital data. To perform this technique, Look up Table (LUT) is created that convert the range of data values to the maximum range of the display device. Based on these LUT’s an enhanced image is produced.

4.4.1.3 Merging of LISS-III and PAN data of IRS-ID
In order to increase the efficiency of feature extraction, LISS-III (4 band, 23.5m spatial resolution, colored data) and PAN (single band, 5.8m spatial resolution, black and white data) data are merged in ERDAS image processing software to obtain a fused data product having 5.8m spatial resolution of PAN data and color from LISS-III data (Fig. 4.2). A hardcopy of this fused satellite imagery is generated for subsequent analysis which helps in better visual interpretation to extract the thematic data by applying pre-visual interpretation, ground truthing and post visual interpretation techniques.
IRS-ID, LISS-III + PAN FUSED SATELLITE IMAGERY

Fig. 4.2: IRS-ID PAN + LISS-III Merged Satellite Imagery of the Study Area
4.4.2 Generation of Thematic Maps

The thematic maps namely, land use/land cover, geomorphology, geology, groundwater prospects map and soil are generated from hardcopy of the satellite digital data. The standard basic elements and key elements for visual interpretation are applied on the satellite hardcopy image so as to extract the entropy or information content in accordance with the above thematic maps. At the end of the interpretation process, the above paper based thematic maps are ready for subsequent scanning and automated digitization for creation of a digital database for GIS data analysis and modeling.

4.4.3 Generation of Topographic Maps

Creating a GIS spatial database is a complex operation, which involves data capture, verification and structuring processes. Raw geographical data are available in many different analogue and digital forms such as toposheets, aerial photographs, satellite imageries and tables. Out of all these sources, the source of toposheet is of much concern to natural resource scientist and an environmentalist. In the present study, the base layers generated from toposheet are,

(i) Base map
(ii) Drainage map
(iii) Transportation Network map
(iv) Watershed map
(v) Slope map
(vi) Physiography map

These paper-based maps are then converted to digital mode using scanning and automated digitization process. These maps are prepared to a certain scale and show the attributes of entities by different symbols or coloring. The location of entities on the earth’s surface is then specified by means of an agreed co-ordinate system. It is mandatory that all spatial data in GIS are located with respect to a frame of reference. For most GIS, the common frame of reference co-ordinate system is that of plane, orthogonal cartesian co-ordinates oriented conventionally North-South and East-West. This entire process is called geo-referencing.
The same procedure is also applied on remote sensing data before it is used to prepare thematic maps from satellite data.

4.4.4 Derived Thematic Maps

Although using remote sensing satellite data and survey of India toposheets for making thematic maps as well as topographical maps is very attractive, serious attention is paid to develop maps showing,

(i) Ground water potential  
(ii) Ground water table  
(iii) Infiltration rate  
(iv) Ground water quality  
(v) Air quality

The first three maps are derived from hydrogeomorphological characteristics and the groundwater quality and air quality maps are prepared from collateral data collected from various related organizations.

4.5 ATTRIBUTE DATA

The attribute data in the present study consists of collateral data, which includes demographic details, solid waste generation rates, ground water levels, water quality data and air quality data acquired from various Government organizations like Andhra Pradesh Pollution Control Board (APPCB), Central Ground Water Board (CGWB), Bureau of Economics and Statistics (BES) etc.
Fig. 4.1: Methodology For Spatial Database Creation
4.6 ANALYTIC HIERARCHY PROCESS (AHP)

For the present study, spatial - Analytic Hierarchy Process (AHP) technique was applied to identify and rank potential sites for solid waste disposal (Fig. 4.3). The AHP decision making method, as used in spatial-AHP involves the following five steps:

1. Identifying the decision factors associated with the problem
2. Structuring them in a decision hierarchy
3. Judging the relative importance of the decision-hierarchy elements
4. Aggregating these measures in order to calculate a suitability index of the alternatives
5. Ranking the elements according to the suitability indices.

4.6.1 Identifying Decision Factors

Decision factors are used to relate attributes to suitability concerning a particular goal, as in this case, selecting potential sites for solid waste disposal. First, the major decision factors are identified. The primary factors which contribute significantly to the site selection criteria include the terrain information, information about the hydrogeological/geological parameters, land use/land cover information, the economic viability of the proposed site and factors based on legal, social, environmental or political restrictions and physical feasibility (presence of water bodies, proximity to roads, etc.).

The decision factors comprised of topographical factors, geological factors, factors ensuring environmental acceptability, hydrological factors, physical feasibility and political restrictions. These factors were classified under two groups, namely, the exclusionary criteria, including the factors based on physical feasibility and political restrictions and the non-exclusionary criteria, consisting of the remaining decision factors. Based on an extensive study, the following criteria have been selected for the present study, the attributes of which are further grouped into exclusionary and non-exclusionary.
Parameters/Criteria considered for site selection

Exclusionary Criteria

- Settlements
- Wetlands
- Flood plains
- Coastal Plains
- Tidal flats
- Sand dunes
- Landslide areas
- Archeological and Historical Sites
- Political Sensitive Areas
- Threatened and Endangered Species

Non-Exclusionary Criteria

- Slope
- Geology
- Soil
- Land use/ Land cover
- Geomorphology
- Groundwater potential
- Groundwater infiltration
- Groundwater table
- Groundwater quality
- Air quality

Conversion of criteria into data layers

Non-acceptable Classes

Buffer analysis

- 200mts from any lake or pond
- 100mts from navigable river or stream
- 200mts from any state or national highway
- 1000mts from a notified habitat area
- 300mts from public parks
- 2000mts from an airport
- 500mt from lineament and faults

Acceptable Classes

Estimation of weightage factor for acceptable criteria based on 9-point scale of AHP

Calculation of relative importance weightage (RIW) of each parameter at different levels of hierarchy

Summarization of RIW at different levels

Evaluation of final suitability index based on RIW values

Ranking of elements based on suitability index

Fig. 4.3: Methodology For Analytic Hierarchy Process
• No landfill should be constructed within 300mts of public parks
• No landfill should be constructed within critical habitat areas
• No landfill should be constructed within wetlands
• A landfill should not be constructed in areas where water table is less than 5m below ground surface
• No landfill should be constructed within 2000mts of an airport to ensure that air traffic is not exposed to bird hazard
• No landfill should be constructed within 500mts of any water supply well to prevent deterioration in the quality of the groundwater
• A landfill should not be sited in a coastal regulation zone
• A landfill should not be located in potentially unstable zones such as landslide prone areas, fault zone etc

4.6.1.2 Non-Exclusionary Criteria

The non-exclusionary criteria are the ones for which the pair-wise comparison of AIIP is applicable. Once the non-exclusionary decision criteria are selected, sub-factors and even sub-sub-factors are identified to better describe these criteria. For instance, terrain information can be categorized into information about the elevation, slope and land use. The information about elevation can be further grouped within selected class-intervals based on the elevation values.

4.6.2 Structuring of Decision Factors into a Hierarchy

All the non-exclusionary criteria are arranged in a hierarchical structure. Level I comprises the goal i.e. selection of best site for solid waste disposal which in turn comprises of four decision factors arranged at Level II of this structure viz., geological, topographical, environmental and hydrological criteria. Geological criteria are in turn divided in to two sub-factors as geology and soil at Level III. Similarly, topographical criteria are subdivided into slope, land use/land cover and geomorphological characteristics; hydrological criteria are classified as groundwater potential, infiltration rate and groundwater table; environmental criteria are divided into groundwater quality and air quality at Level III. All the criteria at Level III are converted into spatial maps from satellite imagery and SOI
4.6.3 Judging The Relative Importance Of The Decision-Hierarchy Elements

Once the parameters are organized into a decision hierarchy, Relative importance weightage (RIW) of each parameter over the other is calculated by pair-wise comparison using the 9-point scale shown in Table 4.3.

Table 4.3: Analytic Hierarchy Measurement Scale

<table>
<thead>
<tr>
<th>Reciprocal Measure of Intensity of Importance</th>
<th>Definition</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Equal importance</td>
<td>Two activities contribute equally to the objective</td>
</tr>
<tr>
<td>3</td>
<td>Weak importance of one over another</td>
<td>Experience and judgment slightly favour one activity over another</td>
</tr>
<tr>
<td>5</td>
<td>Essential or strong importance</td>
<td>Experience and judgment strongly favour one activity over another</td>
</tr>
<tr>
<td>7</td>
<td>Demonstrated importance</td>
<td>An activity is strongly favoured and its dominance is demonstrated in practice</td>
</tr>
<tr>
<td>9</td>
<td>Absolute importance</td>
<td>The evidence favouring one activity over another is of the highest possible order of affirmation</td>
</tr>
<tr>
<td>2, 4, 6, 8</td>
<td>Intermediate values between two adjacent judgments</td>
<td>When compromise is needed</td>
</tr>
<tr>
<td>Reciprocal of the above</td>
<td>If activity i has one of the above non-zero numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i.</td>
<td></td>
</tr>
</tbody>
</table>

Source: Saaty, 1980

The RIWs are the normalized eigenvectors corresponding to the maximum eigen values of the pair-wise comparison matrices constructed at each level of the decision hierarchy. The
RIW assigned to each hierarchy element is determined by normalizing the eigenvector of the decision matrix. Eigenvector values are estimated by multiplying all the elements in a row and taking the nth root of the product, where n is the number of row elements (Siddiqui et al. 1996). Normalization of the eigenvector is accomplished by dividing each eigenvector element by the sum of the eigenvector elements of the decision matrix.

4.6.4 Aggregating The Relative Importance Weightage (RIW) to Calculate A Suitability Index

Once the RIW of each element of each theme or layer to be considered for site selection are calculated, the individual weightages are aggregated/summarized and evaluated. As each of the RIW includes its importance from the first level the final cumulative values will give more accurate results. The suitability index is determined by aggregating the RIW at each level of hierarchy. In this process the RIWs of a cell attribute value is multiplied by the RIW of the associated higher level factors, summing the values for all grouped elements, multiplying those sums by the RIWs of the associated higher level factor, and following the process recursively until the primary non-exclusionary decision factors are reached. The equation for calculating the suitability index is as follows (Erta¸n Yesilnacar and Vedat Doyuran, 2000 and Aditya et al, 2001),

\[
SI = \sum_{i=1}^{N_2} \left[ RIW_{i}^{2} \sum_{j=1}^{N_3} \{RIW_{ij}^{3} \cdot (RIW_{ijk}^{4})\} \right]
\]

Where,

SI = Suitability Index

N2 = Number of decision factors in Level 2

RIW_{i}^{2} = RIW of level 2 decision factor i

N3 = Number of level 3 sub-factors directly connected with level 2 decision factor

RIW_{ij}^{3} = RIW of level 3 sub-factor j of level 2 decision factor i

RIW_{ijk}^{4} = RIW of level 4 attribute category k of level 3 sub-factor j and level 2 decision factor i
4.7 INTEGRATED STUDY FOR SITE SELECTION

The spatial and attribute digital database generated are further integrated for subsequent data analysis in GIS. Buffers are generated for the exclusionary screening criteria e.g. 100m buffer around tanks and other water bodies, 200m buffer around major roads etc. and the area lying within the buffers are excluded for landfill siting. All the non-exclusionary data layers are integrated and overlay analysis performed. All the non-exclusionary criteria considered for site selection are ranked and weighted using Analytic Hierarchy Process (AHP) after the development of decision hierarchy for preparation of a final suitability map for selection of disposal site.

4.8 OPTIMUM ROUTE ANALYSIS FOR TRANSPORTATION OF SOLID WASTE

In early times, the transportation and disposal of human and other wastes produced in the city did not pose significant problem as the amount of waste generated and the distance between the point of generation and disposal was less. But, as the population increased, more land was occupied for residential and commercial purposes. As a result, the dumpsites had to be relocated to far off places in order to reduce its impact on the public health, which in turn requires provision of better transportation facilities for the transfer of wastes to the dumpsites. Therefore optimization of the route or selection of the shortest route to the dumpsite considering the transportation costs including the fuel efficiency is very much essential.

The data required for carrying out the optimal route analysis include ward details of study area, solid waste collection points, transfer stations, disposal sites and detailed road network of study area that include road length and type of roads. The road network map is prepared from the Survey of India (SOI) toposheets in 1:50,000 scale and updated using satellite imagery. These paper drawn maps are converted into digital maps through digitization using AutoCAD and editing process available in ARC/INFO. The lengths of different type of roads delineated from the toposheet are calculated in GIS. The map showing different wards of the study area and the location of solid waste collection points is prepared from the data obtained from Municipal Corporation of Hyderabad (MCH) and Andhra Pradesh Pollution Control Board (APPCB). The location of transfer stations i.e. Imliban (IBT), Lower tank
bund (TBT) and Yousufguda (YZT) and the final disposal sites are stored in separate layers for finding the optimal route.

Software used in finding the optimal route for transportation of solid waste from the existing transfer stations to the final disposal sites is ArcView GIS. This software is a desktop GIS with an easy-to-use, point-and-click graphical user interface (GUI) that easily load spatial and tabular data. ArcView provides the tools needed to query and analyze the data and present results as presentation-quality maps. Network Analyst is an extension product of ArcView designed to use networks more efficiently. It can solve common network problems on any theme containing lines that connect. The ArcView Network Analyst (AVNA) extension module allows the user to solve three categories of network analysis problems: Find Best Route, Find Closest Facility and Find Service Area (ESRI, 1996). Find Best Route problems involve finding the "least cost impedance" path on the network between two or more stops. Find Closest Facility pertains to finding the distances from an event to the nearest facilities, or vice versa, finding the distance from a facility to one or more events. Find Service Area determines the area that a particular facility can serve within a given time or cost frame.

4.8.1 Finding Best Route

A variety of route optimization criteria or planning criteria may be used in route planning. The quality of a route depends on many factors such as distance, travel time, travel speed and number of turns. Some prefer the shortest path based on distance and some prefer based on travel time. The route selection criteria can be either fixed by a design or implemented via a selectable user interface. In the current project route selection is via user interface. In the optimization of the travel distance (road segment length), distance was stored in digital database and the route planning algorithm was used.

After adding the road network theme, there are two options to add the stops for which a route should be calculated i.e. either by interactively selecting stops graphically from the view, or by loading a point theme that holds the stops. In the present study, the location of transfer stations and collection points are added and overlaid onto road network as a point
theme and final disposal site locations are added as a separate theme on the road network. These locations are selected graphically from the view during route analysis. The steps involved in finding the best path with user given origin and destination are presented in Fig. 4.5 and described as follows:

1. Open ArcView
2. Add the road network theme in a view
3. Keep the roads theme active
4. Go to Network > Find Best Route
5. AVNA now adds a route theme to the view and presents a new dialog box.

There are two options to add the stops for which we want to calculate a route, either by interactively selecting stops graphically from the view, or by loading a point theme that holds the stops.

**Selecting Stops Interactively**

1. Click the Add Location icon in the menu bar:
2. Then click in the view to select stops (transfer station and final disposal points).

These are added to the dialog box as we click them. The order of stops can be changed by highlighting (clicking) them. Stops can also be deleted by clicking the delete "X" button. In addition we can use the check boxes to choose whether we want AVNA to find the best order of stops, and/or whether you want to return to the origin (the first stop in the list). Properties allow us to choose the shortest path based on shortest distance.

1. Just add a couple of stops, then click the Solve icon.
2. AVNA will now build the topology and run the analysis. When done, AVNA will add a display route in the window.
3. Click Directions.
4. This gives you turn-by-turn directions for the entire route.
5. Click Done.
6. If there are a number of stops, check the 'find best order box, and then click the Solve icon again to get a different route.
We can save the different alternatives as different routes separately:

1. Make the calculated route active in the View window.
2. Theme > Convert to Shape file > Select a name and a folder > Accept to add the theme to the view.
3. When done running and saving the different alternatives we want to display, delete the default route theme.

The graphical output in the form of a map indicating the route to be traversed along with the distances and directions to be traversed along each road segment gives complete description of the route with least impedance.

Fig. 4.5: Methodology For Optimum Route Analysis
4.9 DEVELOPMENT OF A DECISION SUPPORT SYSTEM (DSS)

The attribute and collateral data obtained and collected during fieldwork and the spatial data prepared during the study (maps obtained) are together related in a user-friendly manner in the form of a decision support system using VB software. This system named as a Decision Support System, is a user-friendly system in which the end user can access the information and make a decision by mere clicking the options. The system is designed in Integrated Development Environment (IDE) and can function on a desktop computer. The flow of application in the development of the decision support system is shown in Fig. 4.6. The flowchart showing the overall methodology and the step-by-step procedure for landfill site selection, optimum route analysis for transportation of solid waste and development of decision support system is presented in Fig. 4.7.
Identification of Criteria and constraints

Creation of maps

Exclusionary

Non-Exclusionary

Population

Solid Waste

Creation of database

Tables

Pie charts

Structuring of criteria into hierarchy

Decision hierarchy structure

AHP

Map analysis

Buffer maps

Binary maps

Overlay maps

Suitability maps

With scrub forest

Without scrub forest

Fig. 4.6: Flow of Application in the development of DSS
Parameters/Criteria considered for site selection

Exclusionary Criteria

Spatial data
- SOI Toposheet
  - Georeferencing (extraction of GCPs)
  - Mosaicking
  - Final rectified toposheet
  - Georeferencing (transfer of GCP on image)
- Satellite Imagery
  - Loading
  - Pre-Processing
  - Enhancement

Data Merging

Final LISS-III & PAN merged output (hard copy preparation)

Topographic Layers
- Base map
- Drainage map
- Road network map
- Watershed map
- Slope map
- Physiography map
- Contour map

Thematic Layers
- Land use/land cover map
- Soil map
- Geology and Structures map
- Geomorphology map
- Groundwater infiltration map
- Groundwater potential map
- Groundwater table map

Integration of data Layers

Overlay Analysis
- Map showing Suitable arcs

Integration of AHP with GIS database
- Creation of final suitability map

Exclusionary criteria application
- Buffer Analysis

Non-Exclusionary/Inclusionary Criteria

Conversion of criteria into data layers

Attribute data
- Groundwater quality
- Air quality
- Solid waste details
- Population details
- Solid waste volume projection for future years

Estimation of weightage factor for non-exclusionary parameters based on 5-point scale of AHP

Calculation of relative importance weightage (RWB) of each parameter at different levels of hierarchy

Summarization of RWB at different levels

Evaluation of final suitability index based on RWB values

Road network map
- Waste collection & disposal points, Traffic volume etc.

Integration of maps
- Identification of origin and destination points for transportation of solid waste

Optimum route selection for transportation of solid waste using Arc View Network Analyst

Integration of Site selection, AHP and Route analysis

Development of Decision Support System (DSS)