

Route Analysis of Transportation of Solid Waste using GIS:A Case Study of Bhopal City

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Abstract: *Solid Waste Management is one among the basic essential services provided by Bhopal Municipal Corporation. In the Present study GIS Arc View 3.2a has been used to find the shortest route for the transportation of Solid Waste. In this study it is shown that by the use of this software, efficiency of transportation of solid waste is increased to a great extent. The present study has thrown light over the areas where improvement can be done. It also suggests the suitability of technology for Bhopal city based on the quality of Municipal Solid Waste of Bhopal city.*

Key words: Solid Waste Management, GIS, Arc View, Route Analysis

INTRODUCTION

Human activity generates solid wastes that are often discarded as a useless material in our society. These wastes are generally disposed off in the environment and they pose a threat to our society as well as environment by causing nuisance, hazards and contamination of surface and ground waters and hence it is necessary to manage the solid waste in environmentally safe manners through proper storage, collection and disposal.

OBJECTIVE OF SOLID WASTE MANAGEMENT

It is seen that disposed waste contains lots of reusable and organic waste like plastics, leather, vegetable waste etc. The first objective of solid waste management should be to reduce the quantity of solid waste disposed off on land by recovering the usable material and recycling the wastes into usable material. Thus by reducing the quantity of waste to be disposed off, we can also reduce the amount of money spent on collecting the waste from the society. Just merely collecting the waste does not solve the problem, so objective should also include disposing the waste into safe places like sanitary landfill.

Effective Management of Solid Waste

By the term effective management, it means that waste management plan should ensure better human health and safety not only for the society but also for the workers engaged in the whole management plan. At the same time, it should reduce the impact on the environment (environmentally sustainable) and should not require huge amount of money, which the society cannot afford for the management (economically sustainable). An effective management system should encourage the people to cooperate in the collection system and to dispose their waste at the proper place. It is seen that it is difficult to minimize two variables, cost and environmental impact, simultaneously. Hence, the balance that needs to be struck is to reduce the overall environmental impact of the waste management systems include the following options.

- Waste minimization at source

- Waste collection and transportation.
- Resource recovery through waste processing.
- Disposal on land i.e. environmentally safe and sustainable disposal in sanitary landfills.

OBJECTIVE OF THE PROJECT

The present research is directed towards development of an integrated solid waste management plan for Bhopal Municipal Corporation (BMC). The various objectives of the present work are to identify and design the following components:

- Acceptable method of storage and segregation of waste.
- Acceptable method of primary collection of waste.
- Acceptable method of bulk storage of waste.
- Acceptable methods of collection and transportation of waste using GIS.
- Method of producing usable products like compost.
- Financial expenditure on whole solid waste management plan.

PROPOSED MSW STORAGE, COLLECTION, RECYCLING FACILITY

The term sorting indicates separation and storage of individual constituents of waste materials.

Objective of Sorting

The following are the objectives of sorting

- To separate and store recyclable material for reuse.
- To separate the waste which can be processed for recovery of materials and energy.
- To separately store hazardous waste.
- To minimize the waste and ensure reduction in landfill space for final disposal.

Stage of Sorting

There are various stages at which sorting can take place in the waste stream.

1. At the source / households.
2. At the community bins (municipal bins).
3. At the transfer station or centralized sorting facility.
4. At the processing sites.
5. At the landfill sites.

In this project two types of sorting facility are employed.

1. At the source
2. At the landfill

Primary sorting at source

There is a tradition in every households in Indian city to keep aside items like news papers, used bottles, jars, pesticides, cans, cloths, strong plastic bags, etc and not to mix with everyday household waste. These are used as items of economical values to be sold or just give away. The waste here is dry and capable of being easily and safely stored at home using suitable plastic bins. So people are to be encouraged for such activity by gifting them a small recycling bin and instructions. No sorting is allowed at

community bins, whatever waste finds its way to the municipal bins (by faults) is directly carried away to landfill without the provision of centralized processing facility.

Sorting at landfill

Organized rag pickers do sorting at landfill. Extra space is provided for this purpose. It is recommended that protection gear for occupational injuries be provided to all rag pickers.

Storage of Waste at Source

Storage of waste at source is the first essential step of SWM. Every household, shop and establishment generates solid waste on day-to-day basis. The waste should normally be stored at the source of waste generation till it is collected for its disposal.

The types of wastes, which can be put in the bins, meant for food waste and biodegradable waste:

- Food wastes of all kinds, cooked and uncooked, including eggshells, and bones etc.
- Flowers and fruit waste including juice peels and houseplants wastes.

- House sweepings

- Households inert (sweeping/ashes)

The types of recyclable and non-bio-degradable waste to be discharged into separate bin include.

- Papers and plastics, all kinds.
- Cardboard and cartons.
- Containers of all kinds excluding those containing hazardous materials.
- Packaging of all kinds.
- Glass of all kinds.
- Metals of all kinds.
- Rags, rubbers, woods
- Foils wrappings, pouches, sachets, and tetrapaks (rinsed)
- Cassettes, computer diskettes, printer cartilage and electronics parts.
- Discarded clothing, furniture and equipment.

Type of bins has been decided based on population density, width of roads, availability of space and minimum travel distance from a house. It has been observed that, if the size of the bins increases then it can serve more number of people but travel distance from a house, and waste load increases, and also if size increases then it exceeds the gap of lifting mechanism of the vehicle and space required to place the bins in the locality. Taking all these considerations into account, five type of bins have been designed for Bhopal Municipality – Type- A, Type-B, Type-C, Type-D1 and Type-D2.

Recycling Facility

Recycling constitutes the beneficial reuse of products that would otherwise be disposed of the main concept of recycling municipal solid waste is to somehow pick up or collect the waste generated by people in their daily lives and then sort the waste so that it can be used in the manufacture of a new product.

There are many ways to implement a recycling program.

- Return of bottle bill containers or use of reverse vending machines.

- Drop boxes, drop-off centres, or buy-back centres for recyclable.
- Material recovery facility for separation of commingled waste
- Fully automated separation of recyclable from raw waste.

Last two programs are costlier and hence avoided. So, first two alternatives will be implemented by providing recycling containers at every designated community locations for recyclable waste. People should be encouraged to use those facilities. Waste thus accumulated will be collected at a proper time. Efforts should be made to sell these recyclable wastes. Type-A bin consists of two compartments one for biodegradable and other for recyclable wastes.

COMPOSTING

Composting is the biological decomposition of biodegradable fraction of organic waste under controlled condition to a state sufficiently suitable for nuisance free storage and handling and for safe use as soil conditioner in land application.

Principle of Composting

The organism actively involved in composing can be classified into six broad groups the groups are bacteria, actinomycetes, fungi, protozoa, worms and some larvae. The bacteria include a wide spectrum of classes, families, genera, and species. Composting can be carried out in two ways i.e. aerobically and anaerobically. During aerobic composting aerobic microorganisms oxidize organic compounds to carbon-dioxide, nitrate and nitrite. Carbon from organic compound is used, as a source of energy while nitrogen is recycled. Due to exothermic reaction, temperature of the mass rises. During anaerobic processes, the anaerobic microorganism, while metabolizing the nutrient breaks down the organic compound through a process of reduction. A very small amount of energy is released during the process and the temperature of composting mass does not rise much. The gases evolved are mainly methane and carbon dioxide. An anaerobic process is a reduction process and the final product of reaction is subjected to some minor oxidation when applied to land.

Classification of Composting

The compost process can be classified in terms of distinguishing cultural condition and in terms of technology.

According to cultural condition.

- Aerobic process and
- Anaerobic process.

According to the technology:

- Windrows system and
- In vessel system.

Properties of Compost

The compost prepared from MSW should be black brown or at least black in colour. It should be crumbly in nature with an earthy odour. The pH should be neutral through slightly acidic or alkaline pH within the entire range of 6.5 to 7.5 can be tolerated.

The compost should neither be completely dry nor lumpy and water should not come out the mass when squeezed. The nitrogen, phosphorus and potassium (NPK) content should be more than one percent each. The nitrogen should be in the form of nitrates for the proper utilization by the plant.

GIS and ARC VIEW

The collection of data about the spatial distribution of significant properties of the Earth's surface in the form of maps by navigators, geographers, and surveyors has long been an important part of activities of organized society. Whereas the topographical maps can be regarded as general purpose maps, the thematic maps for assessment and understanding of natural resources are for specific purpose. The use of aerial photography and remote sensing has made it possible to map large areas with greater accuracy for producing thematic maps of large areas, for resource exploitation and management. Handling of large volume of data for quantitative spatial variation of data requires appropriate tool to process the spatial data using statistical methods and time series analysis. With the introduction of computer assisted cartography, many new tools were developed to perform spatial analysis of the data and to produce maps in desired formats. These operations required a powerful set of tools for collecting, storing, retrieving, transforming, and displaying spatial data from the real world for a particular set of purposes. This set of tools constitutes a Geographic Information System (GIS). A Geographic Information System should be thought of as being much more than means of coding, storing, and retrieving the data about the aspects of earth's surface, because these data can be accessed transformed, and manipulated interactively for studying environmental process, analyzing the results for trends, or anticipating the possible results of planning decisions.

GIS

A GIS is an information system that is designed to work with data referenced by spatial or geographical coordinates. In other words, a GIS is both a database system with specific capabilities for spatially-referenced data as well as a set of operations for working with the data

Components of GIS

The components of GIS can be defined in various ways. But very comprehensively, it can have the following components:

- (i) Computer system (hardware and operating system).
- (ii) Software,
- (iii) Spatial data,
- (iv) Data management and analysis procedures, and
- (v) Personnel to operate the GIS.

Spatial Data

Mapmakers represent spatial features on the Earth's surface as map features on a plane surface. The locations of map features are based on a Cartesian coordinate system with intersecting perpendicular lines along the x- and y-axis, whereas the locations of spatial feature are based on the geographic grid expressed in longitude and latitude values. The transformation from the spherical geographic grid to a plane coordinate system is called map projection. Hundreds of map projections have been developed for mapmaking. Every map projection preserves certain spatial properties while sacrificing other properties. A basic principle in GIS is that map layers to be used together must be based on the same coordinate system. Otherwise, map features from different layers will not register with one another spatially.

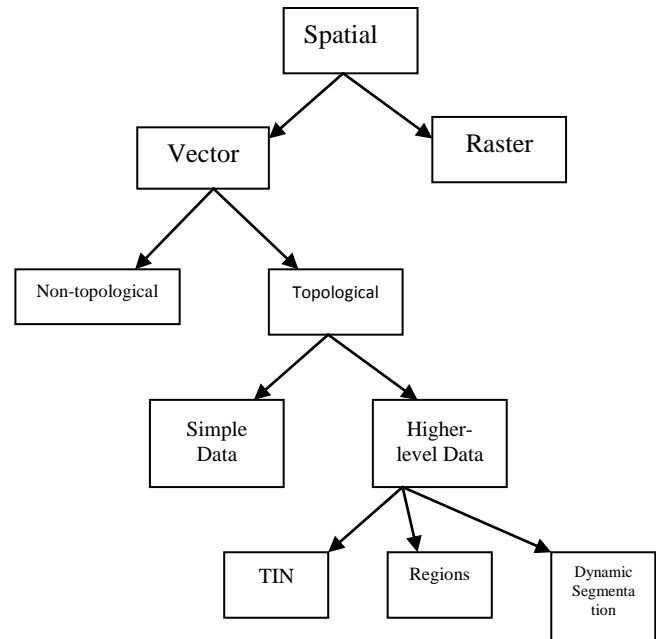


Figure: Data models for spatial data

GIS uses two basic data models to represent spatial features: vector and raster (Figure above). The vector data model uses points and their x-, y- coordinate to construct spatial features of points, lines, and areas. Vector-based features are treated as discrete objects over the space. The raster data model uses a grid to represent spatial variation of a feature. Each cell in the grid has a value that corresponds to the characteristic of the spatial feature at that location. Raster data are well-suited to the representation of continuous spatial features like precipitation and elevation. The data model determines how the data are structured, stored, processed, and analyzed in a GIS. Many GIS functions are either vector-based or raster-based. So are different modules of a GIS package. Arc View provides its raster-based functionalities through the Spatial Analyst extension, and ARC/INFO offers its raster-based commands in the GRID module. Likewise, MGE include the Grid Analyst to work with raster data. Some GIS packages started as either raster-based or vector-based and later acquired capabilities of working with the other data model through strategic partnerships. The data model is not really an issue to the GIS user nowadays. Raster and vector data can be displayed simultaneously. Raster data can be converted to vector data, and vice versa. A GIS has in fact become a useful tool for integrating raster and vector data.

Arc View

Arc View is GIS software, a GIS package developed by Environmental Systems Research Institute (ESRI) lets users see, explore, and analyze spatial data on their desktop. Its basic mapping functionality and advanced geographic information system (GIS) capabilities allow one to create maps showing one's data and integrate and see data in powerful new ways. Arc View GIS enables to present one's work in an attractive manner.

METHODOLOGY

Methodology of Designing the Proposed Solid Waste Collection System

Given below are the sequential steps followed for arriving at suitable collection system.

1. Acquiring Digitised-Map of Bhopal-City in AutoCad-Files, showing all roads and Ward Boundaries with locations of different intersections in the city
2. Creating three Separate Files of Roadnet,RoadNode and Ward-Boundary out of the Single files and saving in Autocad2000 format as ArcView 3.2a is compatible/supports only Autocad2000 only.
3. Rectification and correction of files using Edit-mode of Arview.
4. Rectification of roadmap of city with respect to toposheets
5. Converting the Autocad files into shape files using CadReader Extension of ArcView
6. Add different items in BPL_roads.shp, BPL_nodes.shp and BPL_wards.shp table (using Start Editing command in theme Menu).
Editing commands in theme Menu.

The following items are added in above tables.

In BPL_roads,

Item	Purpose of adding item
Rd-code	Classification of different roads
Fromdistance	Finding distance from start to end of arc
Todistance.	Finding distance from end to start of arc
Speed-limit.	Giving speed of vehicle in different roads
Fromtime	Finding time of travelling from start to end of arc
To time	Finding time of travel from end to start of arc

In BPL_nodes

Item	Purpose of adding item
Bin-type	For classifying different types of containers
Nodename	For naming location in Bhopal
Connections	Which bin type-A collects waste from bin type-C?
Spaorder	For calculating the proximity of bins.
Visit	For calculating the order in which bin are Collected
Capacity	For giving capacity of each bin.
Outclass	For finding groups of bins that are collected in one trip of vehicle.
Stopimp	For giving time needed to pickUp waste at a particular location.

In Bplwards.shp

Item	Purpose of adding item
Ward – no.	For giving different wards number
Population	For giving population data for different ward.

7. Assigning different attributes to the above-created items
8. Saving of work in a stop file using Stopediting Command from theme Menu.

Finding Best Route

What you need : a point theme called BPLwards.shp, a line theme called BPLroads. shp, a polygon theme called BPLwards..shp.Bplwards.shp shows the wardmap of Bhopal city , Bplwards.shp contains the location of the containers, and BPLwards.shp includes the Bhopalroads networks. The objective of this task is to find the best (shortest) route between any two location, measured in kilometers or in minutes. The speed limit for calculating the travel time is 45 Km./hour. The travel time considers only link impedance.

1. Start ArcView, and load the Network Analyst extension. Open a new view, and add BPLwards.shp, BPLnodes.shp, and BPLnodes. shp to view. Select Properties from the View menu. In the View Properties dialog, set the Map Units to meters and the Distance Units to Km. Make BPLnodes.shp active.
2. Use the Query Builder button and the query expression, ([node_name] = "BHEL") or ([node_name] = "Bhanpura") to select.
3. Make Bplroads. shp active. Select Find Best Route from the Network menu to add Route] to the Table of Contents and to display the Route] dialog (this is the Problem Definition dialog for the route).
4. Click Properties in the dialog. In the Properties menu, select Line Length as the Cost Field. Click OK to dismiss the menu.
5. Click Load Stops in the Route1 dialog. Then choose BPLnodes.shp to load stops. After you dismiss the Load Stops menu, you dismiss the Load Stops menu, you should see two stops are added to the Routel dialog.
6. Click the Solve Network Problem button either in the Routel dialog or in the View window. This step calculates the total distance to travel the route. The best route is now displayed in the view. The Routel dialog also shows the total route cost in Km. between BHEL and Bhanpura.
7. If you change the Cost Field from Line Length to Minutes in the Routel Properties menu, the total route cost will be measured in travel time using the speed limit of 45 Km. per hour.

RESULTS & DISCUSSION

Results

The result of the present study can be summarized as follows.

- A solid waste management plan has been developed for Bhopal-city , which encompasses segregation, storage, collection, recycling, composting and landfilling of solid waste.
- Old masonry type dustbins are replaced with five types of cast iron made dustbins, which reduces the time of pickup and improves the primary collection of waste using three types of proposed vehicles.
- GIS is used for selecting the shortest paths to be followed by each waste collecting vehicle on each day.
- Separation of recyclable solid waste is done at the source itself by providing separate three recycling bins at all locations.
- Composting plant is designed for the safe disposal and producing the compost from the waste.

CONCLUSIONS

Following conclusions can be drawn from the present study.

- Cast iron made bins, lifters and skippers are very effective in solid waste collection system.
- GIS is proved to be great tool for solving the optimization of collection routes.
- Recycling of waste at the source itself reduces the waste load to be hauled to the landfill to a great extent and also authorities can generate some revenue from recycling programme.
- By constructing the landfill, the environmental hazards due to spreading, leaching etc of waste can be reduced to a great extent and considerable amount of energy can be recovered from landfill
- New dustbins can be added and the GIS can be used easily to find the new optimized path.
- Cost associated collecting can be reduced to a great extent and at the same time, collection services can be provided to the satisfaction of pollution.

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