Journal of Environment and Earth Science www.iiste.org
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol.5, No.15, 2015

An Investigation on Rout Network Analysis by Raster Method in the Context Sustainable Solid Waste Management A Case of Wolyta Soddo

Bereket Geberselassie Assa
School of Civil Engineering, Hawassa University, PO box 05, Hawassa, Ethiopia

Abstract
The intervention of humans on the natural environment influences the nature of ecosystem processes by the rate at which they operate on environment. In addition to inappropriate solid waste transportation has always negative impact on environment, economy, and ecology heath problem in community. Those are a growing problem for national and local governments to ensure effective and sustainable management of environmental sanitation and due to lack of controlled waste management and Unmanaged wastes transportation often results solid wastes to end up in drains, causing blockages that result in flooding, unsanitary conditions and cause very effective vectors (flies) to spread disease like malaria, including acute water diarrhea and typhoid fever, which are current existing problems in Wolyta Soddo town and the object was developed to conduct suitable route by least cost path method using Geographic Information System (GIS) and Multi Criteria evaluation (MCE) since waste transportation is one part of solid waste management. In addition, In order to active the objective of this research, seven very important factors have been used such are: master plan, land use, road, slope, aspect, source date sate and destination point using the method of weighted overlay technique for all selected factors in Arc GIS 10.1 and IDRISI 32 software to generated Analytic Hierarchical Process (AHP) Eigen vector matrix value.
Keywords: Analytic Hierarchical Process (AHP), Geographic Information System (GIS), Least Cost Path (LCP), Multi Criteria Evaluation (MCE)

1. Introduction

Solid wastes are encompassing heterogeneous mass of throwaways from the urban community as well as the more accumulation of commercial, industrial, and residential wastes. As many scholars showed that the intervention of humans on the natural environment influences the nature of ecosystem processes by the rate at which they operate on environment (*Mengiste Abate a, Jan Nyssen b,, Tammo S. Steenhuis a,c, Michael M. Moges a, Seifu A. Tilahun a Temesgen Enku a, Enyew Adgo d 2015*). In addition to inappropriate solid waste transportation has always negative impact on environment, economy, and ecology heath problem in community. Those are a growing problem for national and local governments to ensure effective and sustainable management of environmental sanitation and due to lack of controlled waste management (*United Nations Environment Program, 2009*). Also as per World Health Organization (WHO) estimations of 2003, the total health-care waste per person per year in most low income countries, is anywhere from 0.5 kg to 3 kg which is one of the case for increases in health problem to citizens of low income countries. (*Hassan, 2005*) and (*Lotfalian and Najafi Caspian, 2005*)

Poor wastes management of towns and cities in most developing countries frequently results waste end up in river, lakes and drains, that causing blockages and result in flooding with unsanitary conditions; this condition is suit for life recycling development of vectors. Flies breed in some part of solid wastes, and they are very effective vectors that spread disease including malaria and chronic diharria (*Tadesse. 2004*). As well as currently such problems main issue in Soddo town due to inappropriate solid waste transportation system and as the town is one of reform in Southern Nation Nationality of Region (SNNPR) of Ethiopia Nevertheless, road side and open drainage solid waste disposal is still the main existing problems in the study area (*Soddo town beautification and sanitation agency as report in 2003E.C.)* This are due to none restructured solid waste management in the town including unsuitability waste transportation system. That may also results in environmental pollution and dreadful odor during transportation to final disposal. In addition, the main source to release hazardous and harmful chemicals to nearby groundwater, surface water and soil to via leachate and via gas to air as carbon emission from river banks as those hazardous solid waste materials end up at river of “Kalte”, “Sharife” and “Galba Shaffa”. As soddo municipality (yearly *report of 2014*) in waste management system, the town administration is strongly working on management system but there is still lack of logical solid waste management system in the town, that was high rendering to pollution of lands, river of the town, groundwater, surface water and cause for the main source of public health problem in the city. And the objective of this study was to minimize this problem by indicate last coast path rout for solid waste material transportation in aspect of both economic and environment pollution management by using Geographic Information System (GIS) with integration Multi Criteria Decision Making (MCDM) in Analytic Hierarchy Process (AHP) for GIS overlay analysis with Multi Criteria Evaluation (MCE) and that perform to identify the optimum rout alignment for waste transportation, (*Ehrogott, 2005*). Therefore, the study focuses on an optimized land use site selection and least cost path based on multi-criteria decision analysis and geo-graphic information system based (GIS) overlay analysis

2. Risk of poor solid waste transportation management

The adapted solid waste transportation system in soddo town is solid waste transportation by home animals through the residential areas until it will reach to disposal site and it was explicitly to the air with the intention of source to release pungent Odor via air during transportation and some of it drops in to ground. As a result, drainages and rivers are highly exposed to contagion and land pollution from those solid wastes (*Wolyta Zone Soddo town Water development Agency 2011*). And 28.5% of people of the town has exposed to air born, severe of vectors born, typhoid fever, endemic typhus fever, malaria, including acute water diarrhea in disease (*Soddo town health Administration annual laboratory 2013*). In addition, a number of drainage systems have a direct linkage to river named “Kalte” this river stream ends up in Lake Abaya see figure in Anx) and (see fig 1.1). And this resulted pollution in this river, surface water and ground water around this area. According to Wolyta Zone Soddo town Water development Agency 2014) “ kalte” river has been using by 10 % of urban and 35 % rural people for drinking and home use purpose due to lack of drinking water in Soddo town.

Fig 2.1 Solid waste transportation systems in soddo town (Source: by author 2013 G C).

Solid waste transportation system in the study area has not been based on multi-criteria analysis approach as conducted by researcher, And (*According to SNNPR of Ethiopia Health Bureau estimation in risk management of environmental pollution protection in 2005 report*), if the problems like listed in above statement will not minimized, Peoples, home animals and ecosystem are under risk In most of the cities of developed countries, waste transportation rout management is the most preferred method for the final disposal of solid waste. Even though, in Wolyta soddo, government and municipalities are already working to develop the sanitary landfill sites, and unmanaged solid waste transportation resulting source of environmental problem. The sites far away from the source of waste generation that increases transfer costs and additional investments for the infrastructure of roads, hence intensifying the financial problems of the making the longer collection and hauling time. These poor transportation management of solid waste in the course of time become haven for scavengers (animals and man alike), due to some end up in derange and open land which increases the most highly risk of infection in the society (*United Nations Environment Program, 2009*). The most conman infections due to this result can be malaria; there are at least 300 acute cases of malaria each year resulting in deaths. The great majority of malaria infections and deaths occur in Africa particularly south of the Sahara .To manage these problems, most of the African counters’ have been used GIS and MCE as a key tool and minimized the environmentally related problems (*Kibrom,2012*). And based on this the study has been collected some important parameters to achieve the objective.

Road planning of solid waste to disposal site

Computer programs can be helpful in route design, especially when routes were rebalanced on a periodic basis. Programs can used to develop detailed micro routes or simpler rebalances of existing routes. To program detailed micro routes, planners require information similar to that needed for heuristic routing. This information might include block configurations, waste generation rates, distance between residences and between routes and disposal or transfer sites, topographical features, and loading times. Communities that already have a geographic information system (GIS) of database and especially good position to take advantage of computerized route balancing the city of Wilmington, Delaware, of USA used a spreadsheet program, average generation rates, and block configuration data to balance the weight of waste collected on each route. The city assumed that loading times were equal in all areas and altered the boundaries of existing routes specific collection vehicle paths were left to drivers. Because of this simple rebalancing, the city was able to reduce its waste collection crew and save collection costs of transportation to the final solid waste disposal site (*Sani Yahaya, 2010*). For smaller communities, rebalancing can be accomplished using manual methods in this study.

Accumulation algorithms

Basic types of algorithms that have been used for routing applications by different scholars, the most popular algorithm is the Dijkstra algorithm (*Jay L. and Mandy J 2002*). This algorithm accumulates all cells with a distance equal from the origin to the target. The accumulation process starts from the target and works its way outward (figure 2.2). In reference to (figure 2.2), the pink cell is the starting point and the purple cell is the ending point. From the starting point, each cell is examined in order of distance from the start and will iteratively search for the next closest cell. For every cell traveled from the starting point cost increases until the ending point found.

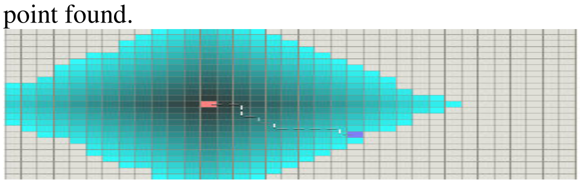


Fig 2.2. Accumulated cell path

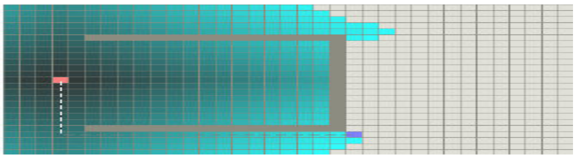


Fig 2.3. Accumulated cell paths with obstacle

accumulates a large area and favors cells closer to the starting point (figure 2.3). It guarantees the shortest path, but accumulates many cells to do this. Another algorithm called the Best First Search (BFS) algorithm accumulates in a heuristic manner, which searches for a path very quickly, by accumulating a small number of cells (figure 2.3). The heuristic trades off a bit in quality of the solution for faster run times. BFS uses an idea of how far it is from the start point to the end. Because of this estimate, it selects cells closer to the end for accumulation before it selects the cells near the start point.

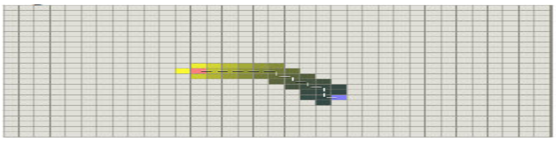


Fig 2.4. Suitable path

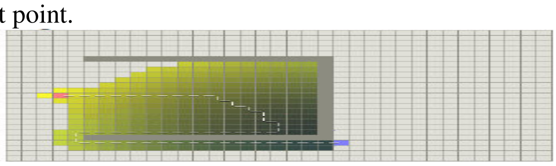


Fig 2.5. Suitable path with obstacle

and (figure 2.4) cells closer to the end point appear darker because they contain a lower heuristic value than those near the start. In this manner, fewer cells accumulated before it finds a solution resulting in fast calculations, but it does not guarantee the optimal result like Dijkstra. (*Dr. Laurence, W. Carstensen, and Jr.2005*). While fast, it also does not prove very useful for barriers . Because it favors cells closest to the target, heuristic estimates result in unwanted backtracking when using the BFS algorithm.

Raster terms and accumulated surfaces

Accumulated surfaces are raster models that allow calculating a least-cost path from point start to point target. The term "accumulated" implies that there is a building up of numbers or values, and this is exactly what happens (*Jay L. and Mandy J 2002*). The cost for a cell in an accumulated surface is a value that represents a cumulative cost from the target. So, to travel across four cells in a row with the first two cells each having a value of one and the second two cells each having a value of two, the accumulated cost to travel through the four cells is six; this value is stored in the start cell. Generally, this type of accumulation is best for modeling real world situations in which travel is complex and involves many decisions. To get good results from a GIS model it must contain all the factors that would play a role in the vehicle's ability to travel. The most efficient means of travel, the least-cost path, is the vehicle's guide between the origin and destination

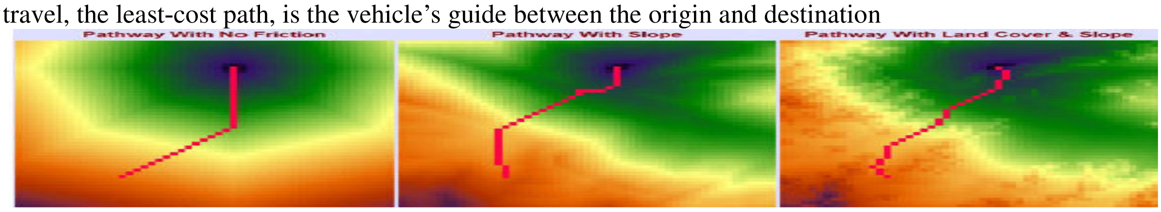


Fig 2.6. Isotropic left Vs anisotropic center and right

Consider bridging and tunneling features. In addition, the designed model to examine slope direction in addition to slope that can create a "zigzagging" (fig 2.7) path that may be fine for road building, but difficult for navigating a vehicle (*Yu, C, Lee, and M. J, 2003*).. They refer to these algorithms as anisotropic because they consider slope direction.

3. Description of the study area and materials

Location

Soddo town is the capital of Wolyta Zone Administration of Southern Nations, Nationalities and Peoples Regional (SNNPR) State, Ethiopia (Figure 3.1). In addition, it has total area of 43.2072 km2 and It is located at about 396 km South west of Addis Ababa. Its geographical extent is between 364500 and 372000m N latitude and between 754000 and 760000m E longitude with altitude ranging from 1400 to 2140 amsl (Ethiopian demography and health organization institute 2005). It has three-kifle ketema and 11 kebels. Soddo is located from Northwest of “Boloss Sore” , from Northeast of “Damote Gale” , from Southwest in “Offa” and from South of “Humbo” in Wolayta Zone Administration of SNNPR of Ethiopia.

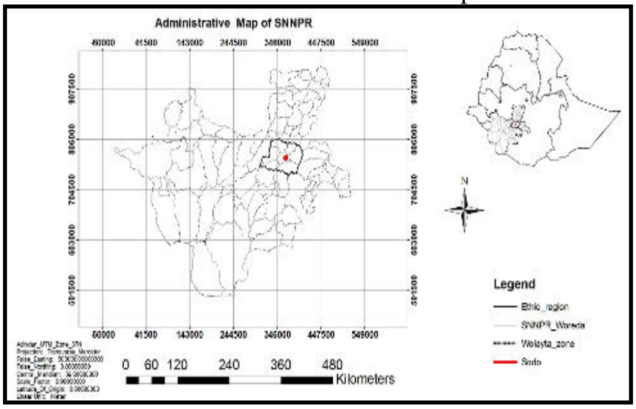


Fig 3.1. Location of study area

Materials

The specific data required for this study were collected (table 3.1) from primary and secondary sources. Primary data of this study were field survey data’s with hand GPS of the ground truth and secondary data has obtained from the local government Authority and SNNPR regional government offices. Analogue map of the study area has obtained from the local government of Wolyta Soddo municipality see (Anx1). A field visit has paid in order to determine the names of features on the analogue map in the attribute field of the digitized copy. The data and their sources used to generate land-use layer, road layer, the least cost path analysis in case of Wolyta Soddo town by using GIS with the integration of Multi-Criteria Evaluation(MCE).

Table 3.1 Data and their sources

Data Types	Sources	Specifications of data	Use of the data
Master plan of the town	Wolyta Soddo Municipality	1:50,000	use to crate required layers such as land use, which is done by digitization
Land use Factor	Wolyta Soddo Municipality	ESRI Polygon Shape file format (*.shp)	Used to (LCP) developments planned.
Elevation/slop factor	Wolyta Soddo Municipality	ESRI line Shape file Format (*.shp)	Contour shape file is used to develop TIN and DEM for further analysis of the study.
Road factor	digitized from land Use	ESRI line Shape file format (*.shp)	Used to analyze proximity zone
GPS data (ground truth)	Filed Survey	Line ESRI Shape File format (*.shp)	To locate sources data set and distention point

4. Methodology of the research

Municipal solid waste management using Geographic Information System and Multi Criteria Evaluation method is the best that was conducted scholars (*Sani Yahaya, 2010*). The contributing factors for suitable selection of least cost path analysis, were developed to a common rescaling option 1 to 5, very low, low, moderate, high, and very high respectively for conducting suitable rout by Multi-Criteria Evaluation (MCE). To run MCE, then selected parameters can be contributing factors were reclassified and weighted and weighted overlay technique was computed in ArcGIS10.1 to generate suitable rout for solid waste to the disposal site based on Analytic Hierarchical Process (AHP) Eigen vector matrix value that are generated by IDRISI 32 software.

Cost distance analysis

The cost distance analysis has performed using the source data set and cost surface as inputs. The source data set were site of spatial location of waste collector stations and cost surface were generated from land use and slope reclassified. The distance dataset created from this tool was a raster in which the value of each cell is the accumulated cost of traveling from each cell back to the source. To find the least costly path, a direction dataset of back link have generated, using the cost distance tool (*Baban and Flannagan, 1998*). This gives a raster of the direction of the least costly path from each cell back to the source to the final suitable site of solid waste dumping site.

Least cost path analysis

GIS is useful tools for identifying the least cost path from source of solid waste to the final solid waste disposal site. One general method is network analysis, which relies on a route system, such a road network is a vector based method. A second method is cost distance/cost path, which is a raster based method and does not use road networks but can be constrained to do so. Based on this, the study has worked with the least cost path method to achieve the objectives and to answer the study questions. To find a least cost path between a starting point or sources data set, a destination point in a given gridded Digital Elevation Model (DEM) have generated in Arc GIS environment, there are two major steps. The first step is to create an accumulated cost surface with respect to all relevant cost factors, which has derived from slope and land use factor and shortest path algorithm is widely used to create a path on an accumulated cost surface for cost identification. The second step is to construct the least-cost path with slope-tracing lines on the accumulated cost surface. It has designed for tracing the shortest path in a network with nodes connected by weighted links (*Jay L. and Mandy J 2002*). To use this algorithm in a GIS grid data layer, a virtual network has constructed fewer than two conditions:

1. The centers of each grid cell serve as the nodes in the network.
2. The connections between the neighboring cell centers act as the links of the network.

The value of each cell represents the cost per unit distance of crossing that cell in the unit of meter, which does not include the existing road (*Jing, J 2007*). Generally, the costs based on following variables: land use, slope based on a digital elevation model and source data set, which is the location of solid waste collectors. And over all analysis as (see in figure 4.1) below

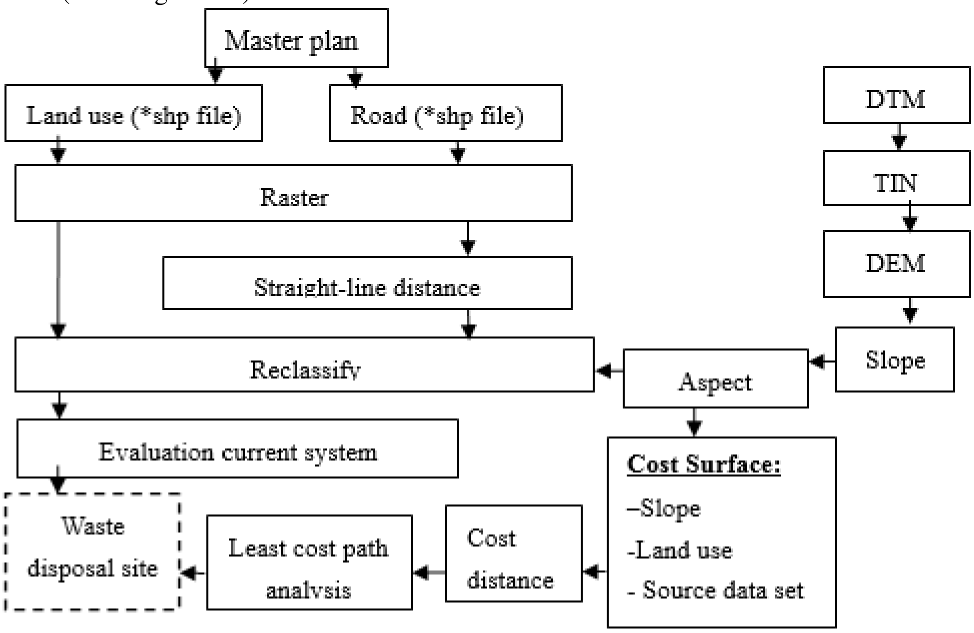


Fig 4.1 Technological scheme of study design

5. Data analysis, results and discussions

Data analysis and results

As scholars achieved in related studies, solid waste management has used geographic information system as a key tool for the reduction of environmental and geographic related problems (*Baban and Flannagan, 1998*).

Table 5.1 Used description of spatial data analysis

No.	Elements used	Descriptions
1	Spatial reference system	Adindan UTM Zone 37N
2	Projection	Transversal Mercator
3	Scale factor	0.999600
4	Linear unit	Meter
5	Datum	Adindan
6	Rescaling option (1 to 5)	5= Very high suitable 4=High suitable 3= Moderate suitable 2=Low suitable 1= Very low suitable
7	cell size	30m
8	Extent	Top =365006.583m Bottom=371563.689m Left =760373.228m Right=753581.826m

Criteria for selecting solid waste disposal site

Criteria used in this study for selection techniques of suitable solid waste transportation to disposal site has been generated depending on Ethiopian town level solid and liquid waste management standard criteria (*S/N/S/P/R Bureau of Urban sanitation and Beautification office 2004*) (table 5.2) below

Table 5.2 Criteria used in this study for selection techniques

No.	Rout selection criteria
1	The selected rout should utilize for a minimum of ten year without any exposures of natural failure
2	The optimal road to final dumping site must be selected with 30 min transportation rout
5	Road proximity to the wetland, park and forest is 500m.
6	Waste transportation should be located at a distance of 10 km far from residential area.
7	Rout allocated must be far from green areas.
8	The rout should not be located at steeps slope.
9	Public service area like schools must be 10km far from waste transportation rout.
10	Waste transportation rout must be 1km far from major road without any traffic crowed.
11	Proximity to river, derange and water body should be in range of 1500m -1700m.
12	To minimize landfill development costs, the requirement for new access road construction generally should be < 10 km for small landfills serving secondary cities

Factor development and reclassification

Land use

Land use type of the town was reassigned by categorizing land use types using Query builder into seven general classes (table 5.3), and converted to raster layer. Further, existing land use types of the town reclassified into seven groups in order of their suitability information. In addition, new values has re-assigned depending on their land use/land cover types giving with the rank for suitable analysis (fig 5.1)

Table 5.3 Rank of land use factor for suitable rout selection analysis

Land use factor	Land cover	Ranking
	Commercial area	Restricted
	Residential area	Restricted
	Grassland and forests	1
	Built-up area	2
	Urban farmland	3
	Proposed land use	4
	Bare land	5

Suitability score of land use reclassified has been according to rescaling option in (table 5.1), the highest suitable value rank of 5 and very low suitable score value of 1 grassland and forest having with commercial and residential areas are restricted area for the suitable solid waste transportation rout alignment

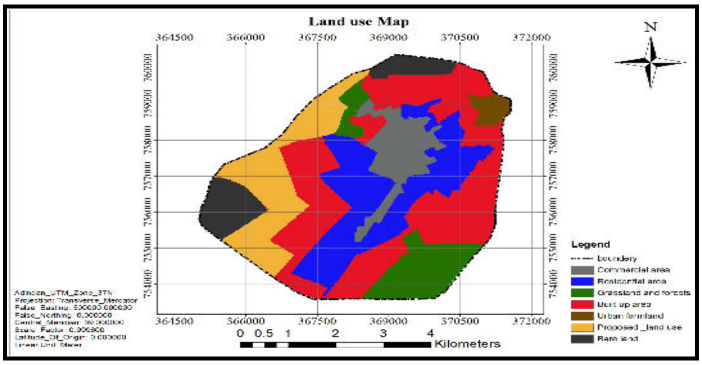


Fig 5.1 Reclassified land use map of the study area

Therefore, this reclassified area (table 5.4) contains listed types of land use/land cover that each of them has a different level of ranking for the selection of suitable rout of solid waste transportation.

Table 5.4 Land use area coverage

Land use factor	Suitability scale	Cell count	In m^2	In (ha)	In (%)
Commercial	Restricted	3856	3470400	347.04	8.032
Residential	Restricted	9727	8754300	875.43	20.2612
Grass land & forest	Very low suitable	4478	4030200	403.02	9.32761
Built up	Low suitable	16327	14694300	1469.43	34.0089
Urban farmland	Moderate suitable	3274	2946600	294.66	6.8197
Proposed land	High suitable	6920	6228000	622.8	14.4143
Bare land	Very high suitable	3426	3083400	308.34	7.13631
Total		48008	43207200	4320.72	100

Slope

Slope factor of Soddo town has developed from contour data of the study area. In addition, use to produced Triangular Irregular Networks (TIN), Digital Elevation Model (DEM) and then to slope. An elevation of the study area range from 1400 - 2140m, and resigned in percent with this regarded slope from 1-2.6(%) percentage was taken as flat and gentle that derived from the DEM for suitable location of solid waste disposal site. And slopes used to identify the maximum rate of change in surface value over a specific distance. In actualizing the slope map from the DEM required for the final study analysis, the spatial analyst tool in Arc Map10.1 was used in the slope map calculation (*Jay L. and Mandy J 2002*).

Table 5.5 Rank of slope suitable analysis

Slope factor	Slope in (%)	Ranking
	1- 2.6	5 =very high suitable
	2.8-4.8	4= high suitable
	4.6-6.4	3= moderate suitable
	6.4-8.2	2= low suitable
	8.2-10	1= very low suitable

The Boolean aggregation demands all criteria has standardized to the same values. Slope data was effectively reduced to these values, areas where the slope that was between 6.4 % to 8.2 % was taken as steep (table 5.5) 8.2% to 10 % were not recommended and was taken as very steep.

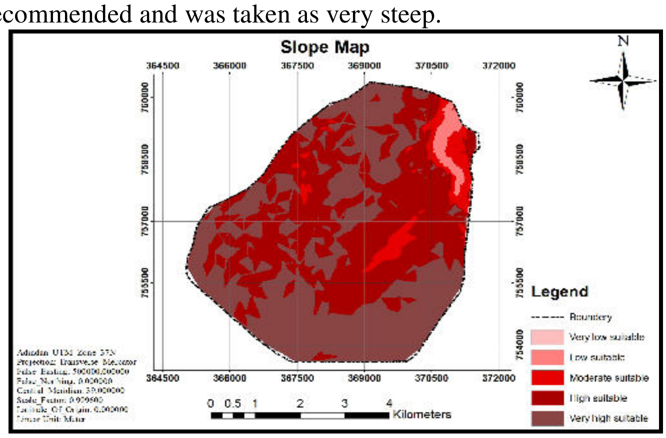


Fig 5.2 Reclassified slope map of the study area

Table 5.6 Slope area coverage

Factor	**Suitability scale**	**cell count**	**In (m)2**	**In (ha)**	**In (%)**
5	Very high suitable	16511	14859900	1485.99	34.39218
4	High suitable	13216	11894400	1189.44	27.52875
3	Moderate suitable	11292	10162800	1016.28	23.52108
2	Low suitable	5251	4725900	472.59	10.93776
1	Very low suitable	1738	1564200	156.42	3.62023
	Total	48008	43207200	4320.72	100

Aspect

As one of the required factor, aspect for this study has identified from down slope direction of the maximum rate of change in value from each cell to its neighbors to indicate the wind direction. The values of the output raster will be the compass direction of the aspect. A new rout should not be located within a distance of a housing area because of the dust and odor emissions. Dependent of the local wind direction and speed (*SNNPR, Bureau of Regional Metrology Annual report, 2004*) (table 5.7), the safe distance necessary to locate a landfill site should be determined to prevent sensing dust and odor.

Table 5.7 Average wind speed in m/s in case of Wolyta Soddo

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	wind direction
2010	1.77	2.65	2.12	1.5	1.24	1.13	0.98	0.91	1.4	1.73	SW to NE
2011	1.05	1.06	2.01	0.5	1.02	1.32	1.1	0.78	2.1	2.01	SE to NW
2012	1.25	1.02	1.27	1.36	2.05	1.75	1.03	1.56	2.02	1.09	SE to SW

Based on the aspect derived from the slope and average annual wind direction, the suitable score has generated by reclassifying in to three classes.

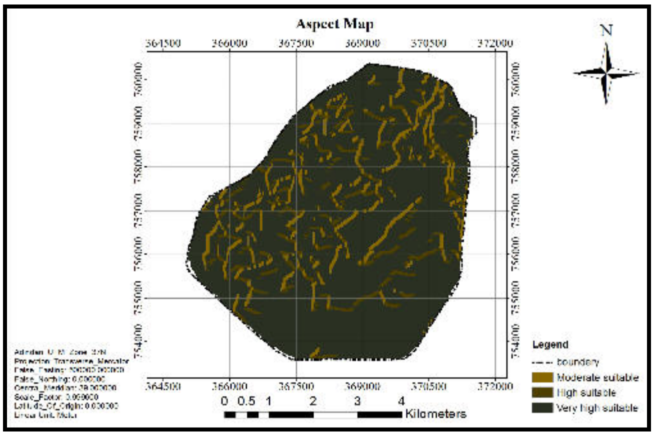


Fig.5.3 Reclassified aspect map of the study area

Road

Road factor of the study area for this study has digitized from the town master plane using line shape file in Arc catalog. The road layer was further calculated proximity to roads of transportation according to the selected criteria (see table 5.2). And reclassified (table 4.12) in five sub groups using standard classification schemes namely equal interval. The highest suitable value ranks of 5 and the least suitable ranks scale values of 1 were assigned (Fig 4.6).

Table 5.12 Rank of road for suitable analysis

Road factor	**Proximity**	**Rank**
	0-199 m	1 =very low suitable
	199-399 m	2 =low suitable
	399-599 m	3= moderate suitable
	599-799m	4= high suitable
	799-999 m	5= very high suitable

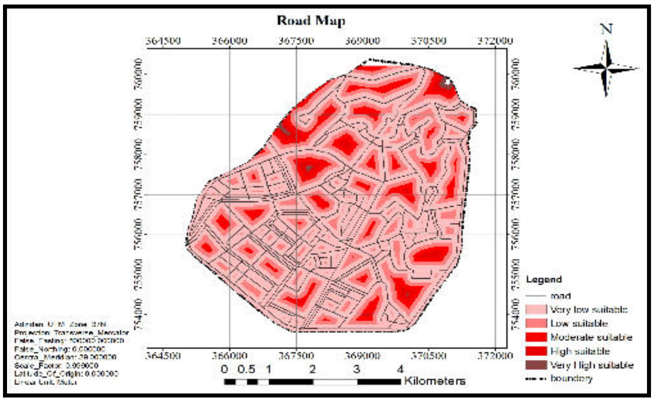


Fig 5.6 Reclassified road map of the study area

Table 5.13 Area coverage of road factor

Rank	Suitability scale	cell count	In (m)2	In (ha)	In (%)
1	Very low suitable	991	891900	89.19	2.064239293
2	Low suitable	2466	2219400	221.94	5.136643893
3	Moderate suitable	4432	3988800	398.88	9.231794701
4	High suitable	10283	9254700	925.47	21.41934678
5	Very high suitable	29836	26852400	2685.24	62.14797534
	Total	48008	43207200	4320.72	100

Least cost path analysis

For solid waste transportation system in Wolyta Soddo, GIS has been used to find a least cost path that is the shortest and optimal path for transportation rout of waste material in order to save time and fuel costs of solid waste transportation as well as minimization environment pollution. Arc GIS's Model Builder (fig.5.16) has been used to automatically perform all processes necessary to calculate cost distances and paths between the stations of source and final suitable site; (*Dj enaliev, A, 2007*). The value of each grid cell represents the cost per unit distance of crossing that cell, (which does not include the physical distance traveled). Generally, least cost path analysis in this study has based on the following factors. The slope reclassified based on a digital elevation model, land use reclassified and source dataset that was the surveyed by using GPS and three location of storage bin were collected using hand GPS (table 5.22). Those container locations were used as source dataset (Appendix 1).

Table 5.22 Location of storage container large-volume generator site

points	Easting	Northing	Projection	Location names
1	36 71 96	75 62 21	(UTM) zone37 N datum Adindan	Fanna kebele
2	37 10 24	75 84 74	(UTM) zone37 N datum Adindan	Kidan mhiter
3	36 90 71	75 41 26	(UTM) zone37Ndatum Adindan	Wadu

Cost surfaces creation

The values of the cost surface, expressed in terms of the particular measure of costs were calculated (equation 4.1) for the estimation of cost value factors. These values often have an actual economic meaning and equal the cost of moving across the landscape. Geographic problems often require the analysis of many different factors for laying a new route, such as land use cost and slope cost (*Djenaliev, A. K 2007*). The cost values calculated relative to some fixed base amount that was given values in the range 1-7 of land use. These values assumed to anticipate the cost of the land use crossing geographical features of certain attributes, where 1 is a very low cost (equal to the base cost), 7 is very high cost (table 5.23). Getting a suitable cost surface is important for the selection of an evaluation scale. But analyzed score has given cost values in the range of 1.4 up to 6.9 outcome was cost surface from land use input and slope input see (fig 5.13) an evaluation scale has been assigned where 0.243 low cost and 5.1142 is high cost and used to finding an optimal traveling route among final site and existing stations. The pair wise has performed for scaling of weight factor for LCP (fig 5.12) below.

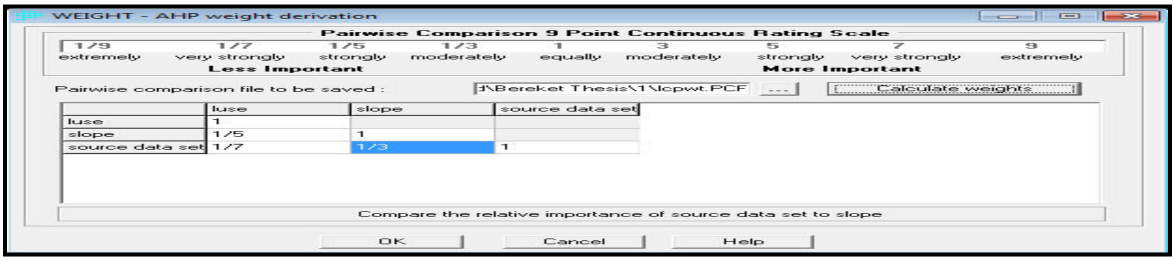


Fig 5.12 Pair wise comparison for least cost path analysis

Table 2.23 Weighted Eigen vector for cost surface analysis

Factor	Weight
Land use	0.7306
Slope	0.1884
Source data set	0.0810

Cost surface=∑ [scale value (sv)*weight (wn)]..5.1

Where,(sv) is scale value, and (wn) is Weight derived from AHP pair wise, comparison (*Djenaliev, A, 2007*)

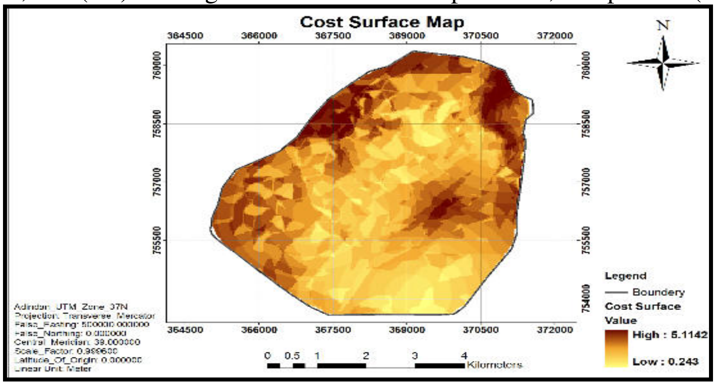


Fig 5.13 Analyzed cost surfaces map

[Cost surface] = (0.7306*[land use] + 0.1884*[slope layer] +0.0810* source dataset)...5.2

Accordingly the following outcome cost value of cost surface has been calculated (table 5.24) below which was used for analysis of cost distance before least cost path.

Table 5.24 Outcome cost value of cost surface analysis

No.	Used factor for cost surface	Weight	Scale value	Cost value	Min. cost	Max. Cost
	Land use /Land Cover	0.7306			0.7306	5.1142
1	Commercial		6.9	5.04114		
2	Residential		6	4.3836		
3	Grassland and forest		5	3.653		
4	Built-up area		2	1.4612		
5	Urban-farmland		1.4	1.02284		
6	proposed land use		2	1.4612		
7	Bare-land		3	2.1918		
	Slope	0.1884	total	19.21478	0.1884	0.942
1	1-2.8%		1	0.1884		
2	2.8-4.8 %		2	0.3768		
3	4.6-6.4%		3	0.5652		
4	6.4-8.2%		4	0.7536		
5	8.2-10%		5	0.942		
	Source data set	0.081	total	2.826	0.081	0.243
1	point 1		1	0.081		
2	point 2		2	0.162		
3	point 3		3	0.243		
			total	0.486		
			Total all	22.52678		

Cost distance analysis

Cost distance has derived from the source dataset and cost surface, in which the value of each cell is the accumulated cost of traveling from each cell back to the location of source data set.

To find the least costly path, a direction dataset have created, which has as an additional dataset used by the cost distance tool. The cost values assigned to each cell are per-unit distance measures for the cell and this cell size has expressed in meters. the cost assigned to the cell is the cost necessary to travel one meter within the cell of data resolution for this study was 30m, the total cost to travel either horizontally or vertically through the cell would be the cost assigned to the cell multiplied by this resolution (ESRI 2002) (table 5.25) below.

[total cost = cost * 30].. 4.2

Total diagonal cost=1.414214 (cost * 30)]..5.3

Table 5.25 Travel cost value of cost distance analysis

No.	factor for cost distance	Weight	Scale value	Cost value	Min. cost	Max. Cost	Total cost	Diagonal Cost
	Land use /Land Cover	0.7306			1.022	5.041	cell size 30	30*1.414
1	Commercial		6.9	5.04114			151.23	213.88
2	Residential		6	4.3836			131.51	185.98
3	Grassland and forest		5	3.653			109.59	154.98
4	Built-up area		2	1.4612			43.84	61.99
5	Urban-farmland		1.4	1.02284			30.69	43.40
6	Proposed land use		2	1.4612			43.84	61.99
7	Bare-land		3	2.1918			65.75	92.99
	Slope	0.1884	Total	19.21478			576.44	815.21
1	1-2.8%		1	0.1884	0.188	0.942	5.65	7.99
2	2.8-4.8 %		2	0.3768			11.30	15.99
3	4.6-6.4%		3	0.5652			16.96	23.98
4	6.4-8.2%		4	0.7536			22.61	31.97
5	8.2-10%		5	0.942			28.26	39.97
	Source data set	0.081	Total	2.826			84.78	119.90
1	point 1		1	0.081	0.081	0.243	2.43	3.44
2	point 2		2	0.162			4.86	6.87
3	point 3		3	0.243			7.29	10.31
			Total	0.486			14.58	20.62
Total all				22.52678			675.80	955.73

Since the cost distance was based on source data set and cost surface, the high and low, value generated from source data set and cost surface (see fig 5.14) below.

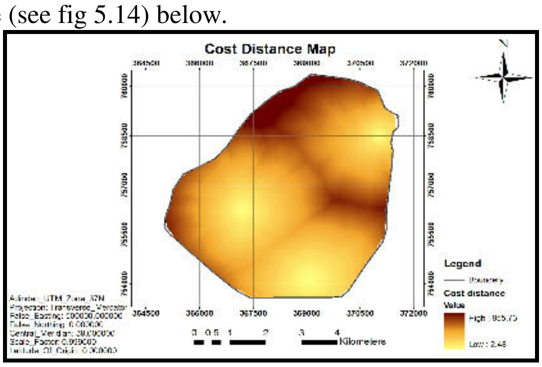


Fig 5.14. Analyzed cost distance map

Least cost path selection

Least cost path has selected from location of waste storage container to pass through cells to reach a final site, the cost path based on the node/link cell representation. Every link has impedance associated with it. This impedance has derived from the costs associated with the cells at each end of the link and the direction of movement through the cells. but the movement is from a cell to one of the four directly connected neighbors, the cost to move across these links to the neighboring node is 1 times the cost of cell 1+ the cost of cell 2 divided by 2.

A1 = (cost*1 + cost*2) / 2... ....5.4

Where cost*1 is the cost of cell 1, cost*2 is the cost cell 2, and A1 is the cost to move from cell 1 to cell 2 (ESRI 2002).

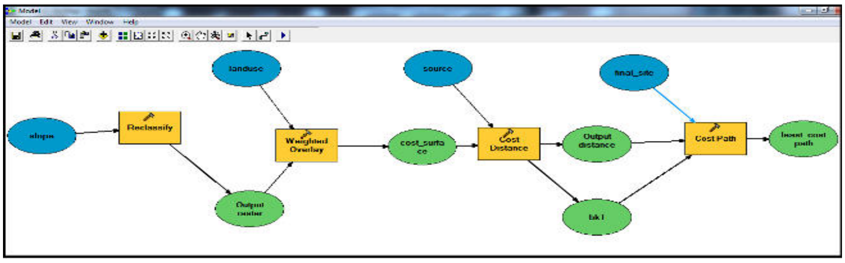


Fig 5.15. Model Builder for least cost path

Accordingly, Arc GIS's Model Builder has automatically performed the cost distance map of the study area (fig 5.15) to find the least cost path to the final very high suitable rout of solid waste transportation (fig 5.16). The cost to move into these cells was calculated using the accumulative cost formulas (equation 5.4) and the active cell on the list with the lowest cost has chosen, from neighborhood that was expanded and the new costs were calculated, all source cells was not connected because all disconnected sources contribute equally compared to the active list. Only the cells with the lowest accumulative cost have chosen from expanded cell of source data sets, and this source cell has allocated. Because the lower source expanded to new location, the cell had access to a cheaper accumulative cost path to reach a final site (*ESRI. Arc GIS 9.0 help, 2004*).

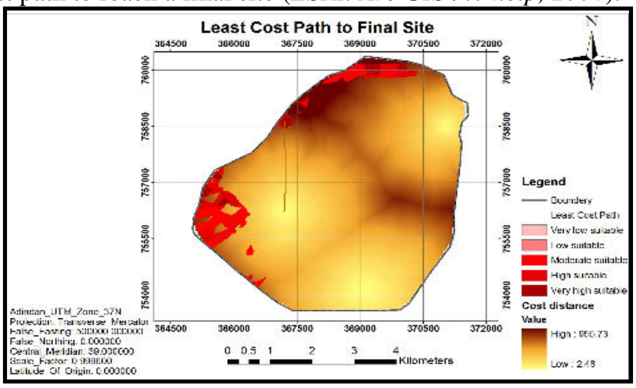


Fig.5.16. Least cost path of solid waste transportation in Wolyta Soddo town.

There for overall analysis of least cost path to the final site of solid waste disposal has pixel cell of 955.73 indicates the cost distance to final site least cost path (fig.5.16) and 2.48 is low cost cell derived from cost distance. Moreover, the least cost path in the study area to the final site from the source 0.015 to 2.45228 can be in kilometer, which is approximately 2.45km (see fig 5.17) below

Attributes of Final_Least_Cost_Path

FID	Shape	ARCID	GRID_CODE	FROM_NODE	TO_NODE	Distance
0	Polyline	1	3	1	3	2.45228
1	Polyline	2	1	3	2	0.015

Record: 1 Show: All Selected Records (

Fig 5.17. Index of least cast path

Discussion

The outcome of this study has showed that the selected suitable rout for waste transportation was aligned in proposed land use/cove of the town. In addition, neighbor's cell of distance from starting point node 2 with cell value of 0.015 has selected to distance of 2.45 km to final suitable site. However, this path used as based line for new road line constriction since the analysis based on pixel or raster term. During analysis to least cost path, land use and slope factor considered for validity cheeked. And maximum land use considered from commercial and residential with cost value of 5.041 and 4.386. Since this value is maximum cost it was not taken for least coat path selection and minimum cost of land use has been selected aligned accrues proposed land use which was the second minimum cost value 1.4612.The slope cost value was selected from slope rang of 1-2.8% with cost value of 0.188. Therefore, there should be relocation of the residents of solid waste deposal site that would reduce high risk to environment pollution.

Conclusion

The study attempts to minimize the problems listed in the current solid waste management system of the study area spatially waste transportation route management, and describes the capabilities of GIS and multi criteria evaluation for the route alignment. The cost factors were then each assigned a relative importance by Analytic Hierarchy Process (AHP) to reflect in the overall scope of the study with acceptable Consistency ratio 0.03 for planning the least cost path in Wolyta Soddo town and (AHP) has been integrated into a decision making process with geographic information system (GIS) to achieve the objective of this study and to answer the study questions. GIS cost path analysis designed of new road that was cost effective due to the routing of waste transportation alignments in this study. In general, the study revealed that 5m landfill depths has selected for final disposal of solid waste in Soddo town. Therefore, the output of this study can be used as for minimization of environmental related problems due to poor waste management in the town.

References

Baban and Flannagan, 1998. “Developing and Imple-menting GIS-assisted Constraints Criteria for Planning Landfill Sites in the UK,” Planning Practice and Re-search, Vol. 13, No. 2, pp. 139-141.

Boroushaki S. and J. Malczewski.2008 Implementing an Extension of the Analytical Hierarchy Process Using Wrdered Weighted Averaging Operators with Fuzzy Quantifiers in Arc GIS Computers & Geosciences, University of Stuttgart , Germany . (34), pp. 399–410.

Djenaliev, A. K, 2007. Multi criteria decision making and GIS for railroad planning in Kyrgyzstan Master’s of Science Thesis in Geoinformatics TRITA-GIT EX 07-007. School of Architecture and the Built Environment Royal Institute of Technology (KTH) 100 44 Stockholm, Sweden.

Dr. Laurence, W. Carstensen, and Jr.(2005) Accumulated Surfaces & Least-Cost Paths: GIS Modeling for Autonomous Ground Vehicle (AGV) Navigation. the faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of the requirements for the degree of Master of Science Geography. Virginia.

Eastman J. R.1997. Idrisi for Windows, Version 2.0: Tutorial Exercises, Graduate School of Geography – Clark University, Worcester, MA.England.

Ehrogott, M. (Eds.), 2005 Multiple criteria decision analysisfor the selection of suitable solid waste disposal site Decision Conferencing, website Source: http//:<www.decision-conferencing.com/> may.23/2012.

ESRI. ArcGIS 10.1 Help, 2004. Online Manual. Environmental System Research Institute Inc., Redlands, California.

ESRI, 2002. Breet, B.O, Bruce, P.A, Jason, W.I, Kevin, J.O, Steve, K.O. Using Arc GISR® By. National Park Service, Department of the Interior. U.S. Government

Hassan, Chong L., and Rahman. M. Solid Waste Management-What’s The Malaysian Position. Seminar Waste to Energy, University Putra Malaysia 2005.

Jay L. and Mandy J 2002. Extensions to least-cost path algorithms for roadway planning, Department of Geography, Pennsylvania State University, State College, PA 16802, USA, . Vol 17,No. 4, 361–365.

Jiang and J. Toledano ,1998 . GIS and Multi criteria Decision Analysis, John Wiley and Sons, Toronto.Eastman J. R., H. Poland pp. 227–231.

Jing, J 2007.. Analysis of the Suitable and Low-Cost Sites for Industrial Land Using Multi Criteria Evaluation: A Case of Panzhihua, China. Royal Institute of Technology (KTH)100 44 Stockholm, Sweden,. Pp (6)_123_125.

Kibrom. Hailu. Msc thesis, Malaria Risk Assessment using Geographic information system, Adama University department of Geodesy and Geomatics Engineering. Adama Ethiopia 2012.

K. L; Majumdar, and D. S. Kumar 1991. A Weighted Index Model for Urban Suitability Assessment – A GIS Approach. Bombay Metropolitan Regional Development Authority, Bombay, India

Lotfalian and Najafi Caspian J. Planning road network in mountain forests using GIS and Analytic Hierarchical Process (AHP), University of Guilan, Printed in I.R. Iran 2005. Env. Sci. 2010, Vol. 8 No.2 pp. 151~154.

Malczewski, J. 2004. GIS-based land-use suitability analysis: a critical overview. Progress in Planning, Poland pp62 (1), 63–65.

McHarg, I.L. 1969, Design with nature. The Natural History Press, Garden City, NY. Scotland ,. Journal of Environmental Engineering120 (5), 1095–1108.

Pearlman, J.S. Barry, P.S. Segal, C.C. Shepanski, J. Beiso, D. and Carman, S.L. Hyperion, a Space-Based Imaging Spectrometer. IEEE Transactions on Geoscience and Remote Sensing,41(6), 2003,1160-1173.

Raju, P.L.N 2009.. Spatial Data Analysis: Satellite Remote Sensing and GIS Applications in Agricultural Meteorology pp. 151-174 Geoinformatics Division Indian Institute of Remote Sensing, Dehra Dun. Indian

Rwanda Environment Management Authority. 2010., Practical Tools on Solid Waste Management of

Imidugudu, for Small Towns and Cities Republic of Rwanda Kigali, . source http://<< www.rema.gov.rw>> Sunday, August-30-15

Saaty, R.W.,2004. GIS-based land-use suitability analysis: a critical overview. Progress in Planning, Poland, 2004. volume I 62(1), pp. 63–65.

Saaty, T, 2004. The Analytic Hierarchy Process. McGraw-Hill, New York ,1980, pp. 20-25

Sani Yahaya, 2010 , Land Fill Site Selection for Municipal Solid Waste Management using Geographic Information System and Multi Criteria Evaluation, American ,2004. Journal of Scientific Research ISSN 1450-223X Issue 10 (2010), pp. 34-39

Sener, S., et al., 2010. Solid waste disposal site selection with GIS and AHP methodology: a case study in Senirkent-Uluborlu (Isparta) Basin, Turkey: Journal of Environmental Monitoring

Siddiqui, M.Z. et al., 1996. Landfill siting using Geographic Information Systems: a demonstration. Journal of Environmental Engineering, 122 (6) 515–523 Source: http// <www.sciencedirect.com> 11/ may/ 2012.

SNNPR,. Bureau of Regional Metrology Annual report, Department of Metrology Ethiopia, 2004.

S/N/S/P/R. Bureau of urban sanitation and beautification office. Ethiopian Government Dec/20/2004.

S. J. Baban and J. Flannagan, "Developing and Imple-menting GIS-assisted Constraints Criteria for Planning Landfill Sites in the UK," Planning Practice and Re-search, Vol. 13, No. 2, 1998, pp. 139-151

Source: Ethiopian demography and health organization institute 2005. http//:www.ethiodemographyandhealth.org/Fev/06/2013.

Tadesse. T 2004. Solid Waste Management for For Environmental and Occupational Health Students. In collaboration with the Ethiopia Public Health Training Initiative, The Carter Center, the Ethiopia Ministry of Health, and the Ethiopia Ministry of Education. University of Gondar ,Ethiopia , Pp14-15

United Nations Environment Programme. Developing Integrated Solid Waste Management Plan Training Manual Volume II. Division of Technology, Industry and Economics International Environmental Technology Centre Osaka/Shiga, Japan, 2009.

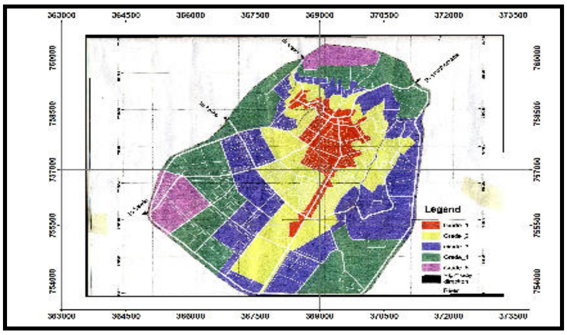
Wolayta soddo zonal hospital Annual Laboratory report, Department of Laboratory , Ethiopia , 2003 EC. 01 May 2012.

Wolayta Zone Soddo Municipality Department of beautification and sanitation agency, Annul Report 2002/2003EC. . 15 May 2012.

Wolayta Zone Soddo Water development Agency. Department of Water Supply , Ethiopia ,2003 EC .

Yesilnacar, M. and Cetin, H., 2005. Site selection for hazardous wastes: A case study from the GAP area, Turkey. Engineering Geology, 81, 371–388. Source : http//: www.onlinelibrary.com / 23/may/2012.

Yu, C.,. Lee, and M. J, 2003 Extensions to Least-Cost Path Algorithms for Roadway Planning Chain. International Journal of Geographic Information Science 17 4: 361-366



Factor developed map of the study area

Appendix 1 Container sites