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Using GIS to Select Ideal Sites for Municipal Wastes Transfer Station: *Case Study of Embu Municipality*

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Abstract: In Kenya, many local authorities face uphill challenges in dealing with wastes especially volume reduction and proper disposal. There is minimal solid waste segregation and recycling further compounding the problem of open dumping. The study's objective was to identify suitable areas to consider for the construction of a multi-purpose waste transfer and recovery facility within Embu municipality. There was also a need to popularize waste bulking and improve on ways of compiling waste data which was lacking in their municipal waste management system. The study used a mixed approach design encompassing ground surveys, interviews, questionnaires, data modeling and Analysis. In this case study, Geographic Information System (GIS) was used to evaluate Population, land use and proximity to waste receptacles as impact factors influencing waste management in this town. GIS-based analysis identified Kangaru, Blue valley, Majengo and Itabua Wards as suitable areas for the construction of waste transfer station. The identified regions contained a total area of 0.15km^2 of suitable sites from the initial 0.40km^2 identified as Preliminary sites. These wards had motor able roads, with agricultural land use and were within the town suburbs. GIS provided appropriate tools for compilation, analysis and management of information related to generation, collection and disposal of Municipal Wastes. The study recommends the adoption of an integrated waste management approach where public views and the use of geospatial tools are incorporated in all aspects of municipal waste management.

Keywords: Waste Transfer Station, Geographic Information Systems (GIS), Municipal Solid Wastes (MSW)

1. Introduction

1.1. Background Information

Economic growth, urbanization and industrialization are contributing to the rise of Solid waste menace in Kenya's urban areas. Mixing up of wastes has continued to pose a challenge on volume reduction and waste segregation. Source reduction and recycling also play an integral role in any community's total waste management system (US.EPA, 2000). Therefore, if most Municipal Solid wastes were segregated, reduced or recycled, a significant amount could be diverted from dumpsites and instead turned into revenue generation materials.

All these activities would minimize the quantity as well as the weight of the wastes ending up in the disposal sites therefore reducing the costs of transportation as well as disposal. The Municipal Solid Waste can be defined as discards routinely collected from homes, businesses, institutions, and the nonhazardous discards from industries (Lund, Herbert F, 1992). Usually municipal waste is the most widespread waste stream in developing world today requiring major financial and logistical resources to collect, recycle and dispose.

On a global scale, municipal solid waste is increasing, calling for the current recycling levels to be raised further (Global Market waste report, 2007). A need for commercial infrastructure to support recycling and even a need to reduce the amount of wastes produced at the source underpins the value of a Waste Transfer Station in an expanding municipality like Embu.

1.2. Importance of Waste Transfer Stations in Solid Waste Management

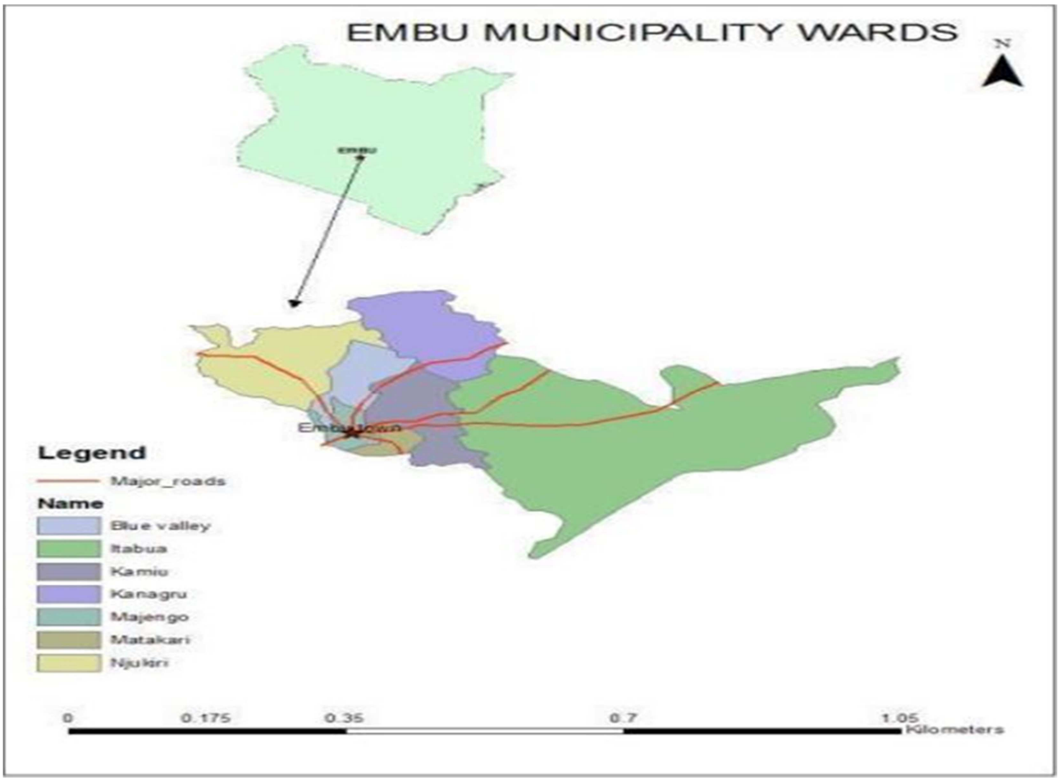
These are facilities where municipal solid waste is unloaded from collection vehicles and briefly held while it is reloaded onto larger long-distance transport vehicles for shipment to landfills or other treatment or disposal facilities (National Environmental Justice Advisory Council, 2000).

By combining the loads of several individual waste collection trucks into a single shipment, communities can save on money for the labour and operating costs of transporting the waste to a remote disposal site. They can also reduce the total number of trips traveling to and from the disposal site. Wastes transfer stations reduces on labour, fuel and collection costs by consolidating solid waste collection and disposal points, minimizes the cost of hauling waste to distant disposal sites (Solid Waste Association of North America. 2000). Generally around the world, Wastes transfer Stations are becoming popular especially in the United States of America because such facilities have the benefits of reducing overall traffic by consolidating smaller loads into larger vehicles, they offer flexibility in waste handling and disposal options, help reduce air pollution, fuel consumption and road wear by consolidating trash into fewer vehicles, Allow for screening of waste for special handling and giving citizens facilities where they can drop-off generated waste and recyclables (US.EPA, 1995).

In any community's waste management system, waste transfer stations now links waste collection program and disposal facility emphasizing the crucial role of such facilities play in any local or regional waste management system. Currently, Embu municipality is experiencing a lot of recycling activities both in plastics and old metals. As an initiative to encourage recycling, minimize illegal dumping and offer convenient, cost effective place for people to drop off wastes, there is a need to set up such a facility where wastes is first collected and consolidated before finally transported to the recycling plants or the landfills. Wastes transfer stations also can serve as wastes drop-off stations and or Material Recovery Facilities (MRFs). As an approach to support the Embu urban community waste reduction and raise the current recycling levels, a waste transfer Station was considered appropriate given the population growth and uncontrolled urban waste stream.

1.3. Study Area

Embu town lies between Latitude 0° 32' 24"and 0° 32' 46" South, Longitude 37° 27' 01"and 37° 27' 31" East. The township occupies a total area of 80 square kilometers and is approximately 150 kilometers North East of Nairobi. The area receives on average annual rainfall of 1495mm with two rainy seasons corresponding to April and October. The temperature ranges from 12°C to 27°C with the coldest and hottest months being July and March respectively. Embu township municipality has seven electoral wards namely; Njukiri, Majengo, Itabua, Matakari, Kamiu, Kangaru and Blue valley (figure 1). The township has a population of about 150000 persons according to the Kenya National Bureau of Statistics census report of 2009.



(Source: Author)

Figure 1. *A map of Embu Township Municipality Wards.*

1.4. Current Waste Situation and Management Practices

Embu Municipal Solid Wastes is composed mainly of organic matter, debris, metals, plastics, ash, papers and non-hazardous medical wastes from the chemists and clinics operating in the municipality. Embu town is a home to many businesses, government departments and non-governmental organizations. This contributes waste inputs from commercial, residential and service oriented sources.

The current garbage collection services do not extensively cover all the source points especially the residential estates but only the town center. The town has huge piles of wastes openly dumped along the road reserves, front yards and open spaces as shown in palte 1. The existing temporary waste receptacles are small and cannot handle the increasing garbage load leading to open littering (plate 2).

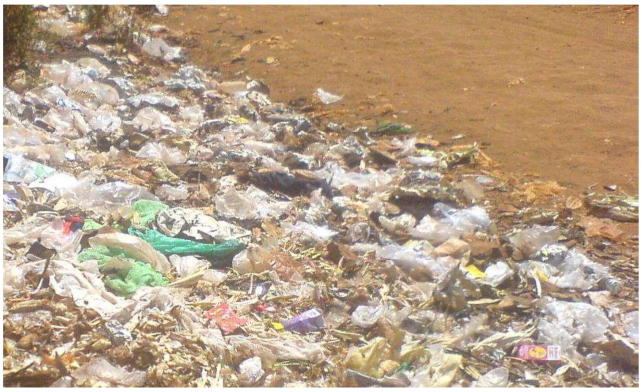


Plate 1. *Open Dumping on streets.*

Plate 2. *A waste receptacle in town center.*

The objective of the study was to identify most suitable areas within the municipality where all generated wastes from the township could be temporary stored for separation, sorting and bulking before final disposal and even recycling. As the municipality expand, the volume of the waste stream has increased tremendously leading to mixing of wastes which would otherwise been separated for sale as recyclables to generate revenue for supporting waste management practice.

2. Determining Transfer Station Size and Capacity

2.1. Nature of the Waste Transfer Station

The proposed transfer station is meant to serve the Embu municipal solid wastes especially from the demolition and construction, Yard and household trash. In line with this, the facility would be planned to accept wastes from both private and the public sources. In the choice of a more convenient transfer station to adequately cater for the wastes from wards, service area, amount of wastes generated, vehicles for haulage, arrival and offloading duration and the existing waste management facilities were considered. In this case study, a direct dump station with a capacity of 70 tons per day was adopted.

2.2. Calculating Optimum Holding Capacity

The formula was used to calculate the load capacity of the desirable waste transfer station was the one adopted from decision-Makers Guide to Solid Waste Management.

$$C = Nn \times Pt \times F \times 60 \times HW / [(Pt/Pc) \times (W/Ln) \times Tc] + B$$

Where; C is Station capacity (tons/day)
Pc is Collection vehicle payloads (tons)
W is Width of each dumping space (feet)
HW is Hours per day that waste is delivered
Tc is Time to unload each collection vehicle (minutes)
F Peaking factor (ratio of number of collection vehicles received during an average 30 minute period to the number received during a peak 30minute period)
Pt is Transfer trailer payload (tons)
B is Time to remove and replace each loaded trailer (minutes)
Nn is Number of hoppers
Ln is Length of each hopper
(Source: *Decision-Makers Guide to Solid Waste Management, Second Ed, p. 4-23*)

3. GIS and Solid Waste Management

3.1. Overview of Geographic Information Systems Applications in Waste Management

Most literature reveal that GIS has been widely used in the solid waste management. Several GIS integrated systems have been implemented in the areas of suitability analysis, planning and optimal garbage trucks routing studies. For example, appropriate landfill sites selection (Ramuu & Kennedy 1994, Kao & Lin 1996, Haastrup *et al*. 1998, Leao *et al*. 2001, Ramasamy *et al*. 2002, Al-Jarrah & Abu-Qdais 2006), the location of recycling drop-off stations (Chang *et al*. 2000), the precise estimation of solid waste generation using the local population density and income group distribution (Vijay *et al*. 2005).

For this reason, GIS has found more use because it can handle different data formats simultaneously. In the planning and management of Solid waste, varied data sets need to be aggregated together to help in integrated understanding of the fuzzy patterns of wastes generation. Based on this, GIS can give analytical perspective of the existing situation and a future trend can be predicted to help in the long can term planning of waste management. In this study, GIS was be used to integrate several datasets in a layer based approach and help narrow down the search for suitable areas where a municipality transfer facility could be constructed.

3.2. Site Selection Criteria

Identifying the most appropriate site for the location of any waste management facility is usually challenging and time consuming. In this case study, where the need was to identify suitable areas from many wards in a municipality, several factors such as Population, Slope, road networks and administrative policies were considered most important. The criteria for selection used was based on the area's specifications with the following variables having the most weight:

3.2.1. Topography

Usually a relatively gentle landscape was used because such areas allow quick drainage and minimize construction costs associated with the excavation and erection of retaining walls. Similarly completely flat areas were avoided since they were found not conducive especially if the Transfer stations were multilevel buildings requiring vehicle access at several levels of the facility would need a ramp to be constructed. Therefore a slope of not less than 15% and not greater than 25% were considered as gentles slopes appropriate because of the existing area's relief.

3.2.2. Space

The ability for expansion was not ignored because the volume of wastes will keeping on increasing as more residential and commercial buildings are constructed to cater for the increasing housing demand for the area's urban population. Basing on the data gotten from daily collections records at the cleansing department, monthly waste projections were calculated for plan for a site which could offer big roads for vehicles allowing incoming and outgoing traffic to occupy space inside the facility's compound and not waiting along the public roads. To enhance the separation from sensitive adjoining land uses, adequate open spaces are considered to buffer the impacts of traffic noise expected to be generated from the facility.

3.2.3. Transportation Routes

Access routes to and from the waste transfer Station should help significantly minimise risks of accidents, Air emissions and noise. In order to ensure efficient waste collection, it was found that the proposed transfer station should be located within the reach of most waste collection routes preferentially less than 16 kilometers from the edge all collection routes.

3.2.4. Land Use

The areas with minimal residential activities and more of industrial use were considered appropriate as candidate sites for the facility. Because the areas lie within a municipality, Zoning ordinances and designated land uses were considered. To reduce protests from the adjacent communities and mitigate conflicting industrial uses, stakeholders drawn from the township's diverse population were consulted in identifying areas not likely to suffer from clustering and encroachment. Using the existing land use zonings from the department of physical planning, areas finally accepted as ideal sites were screened and found to meet the council by law on zoning and could have minimal impacts on the surrounding people.

4. Data and Materials

Mainly primary data was used in this study in the form of cadastral maps and attribute data. Catalinx Spatial Builder was used for digitization and Vectorisation of the township cadastre map while Idrisi Kilimanjaro was used for spatial modeling and analysis.

4.1. Methodology

This study used both qualitative and quantitative data. The Methodology adopted for this case study included Ground based analysis, Data modeling and Analysis within GIS Environment. Questionnaires were used to collect data about the residents' opinions on the municipal council's input to the solid waste management.

Questionnaires sought to know the respondents' area of resident, their conversant with the municipal council's bylaws and what they thought could be done to avert the problems of waste disposal. Personal face to face interviews were also used. Four interviews were carried out on district environmental officer, cleansing superintendent, public health officer and physical planning officer of Embu. Several open observations were done by visiting the waste loading and offloading areas, the dump site, the waste receptacles and residential estates. Photographs taken from the sites formed the basis for understanding and analysing the current waste situation in the selected estates.

GIS was used in modeling, analysis and a decision support system. GIS modeling and analysis were carried out using Idrisi Kilimanjaro. Spatial data was generated through digitization of a cadastral sheet of the scale 1:50000 for Embu municipality boundary (figure 2.) This was done in Catalinx Spatial Builder software to generate coverage for the study area. Attribute data for the layers were developed from primary data, the municipal council of Embu strategic plan and the cadastre sheet of the study area.

The data in the form of maps are entered and then each positive attribute or exclusionary criteria for siting transfer stations was layered on top of other input maps to narrow down potential site locations. The resultant maps show the relationship between input maps layers which were subjected to evaluate based on the existing municipality by laws.

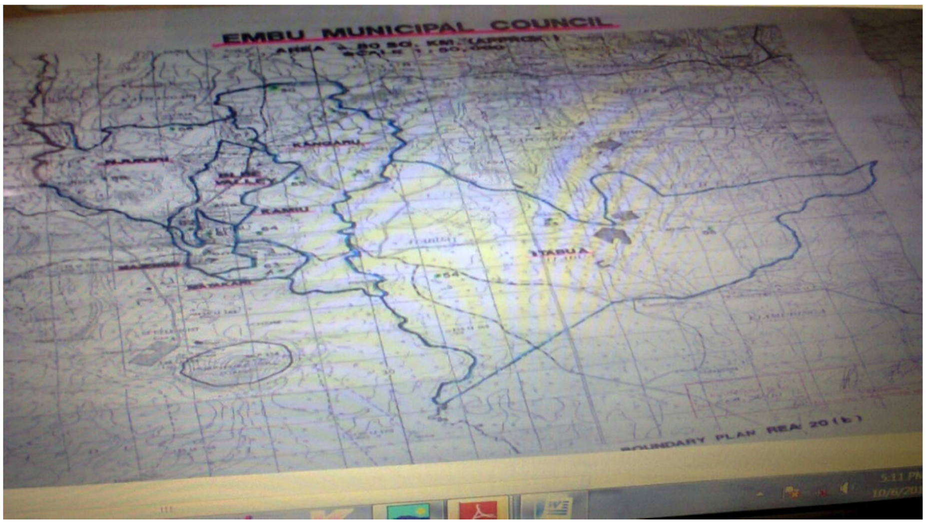


Figure 2. *Cadastral sheet of Embu Township Municipality.*

4.2. Modeling and Analysis Within a GIS Platform (Idrisi Kilimanjaro)

The study area's cadastre sheet was obtained from the physical planning department in Embu. It was scanned and then geo-referenced in UTM Zone 37 South, Arc1960 datum and spheroid of Clarke 1880 in Catalinx Spatial Builder software. Features of interest developed from the cadastre Sheet include roads, wards and contours. These spatial features were digitized from the cadastre sheet. Other attribute information was gotten from the Municipal Council of Embu strategic plan 2007/2012.

Most of the attribute information was collected from the field survey. The resultant products were municipality land use map, roads networks, population and slope layers for use in spatial analysis. For ease of analysis, rasterisation was done on the vector layers were exported to Idrisi32 and converted to Raster. Buffering was used to calculate the zones beyond the existing receptacles and roads. Query by attribute was used to identify the land uses existing in a given area. Then Reclassification was used to create Boolean images with the suitable land uses assigned a value of 1 and Non-suitable areas a value of 0.

Positional coordinates were collected in the field using Juno SD GPS receiver. Boolean images for each of the layers were created and then overlaid to give a suitability map of each layer.

Then the resultant map layers were overlaid together to get preliminary sites for consideration. The final suitability map was gotten by ranking the sites basing on then council bylaws.

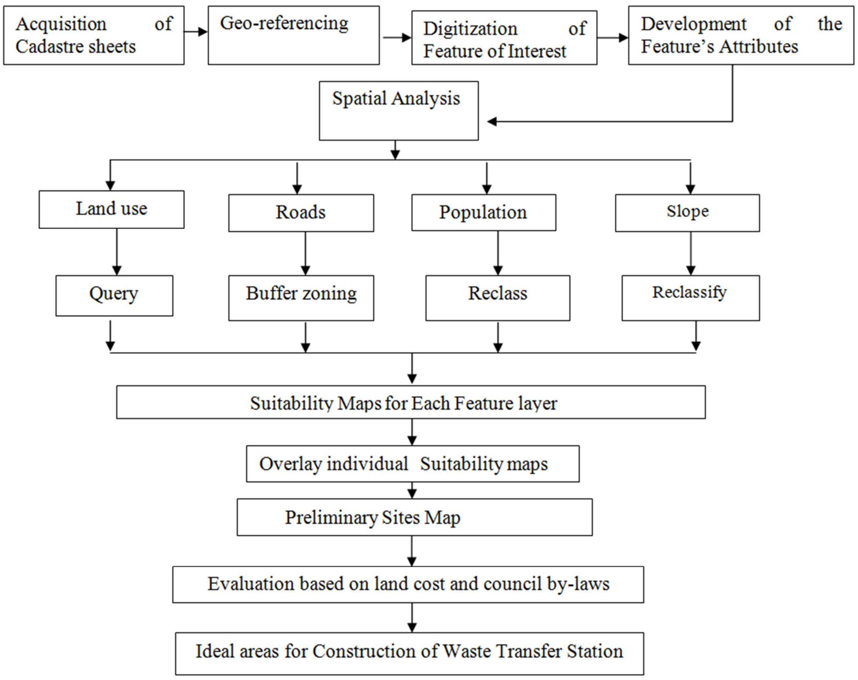


Figure 3. *Conceptualized GIS methodology used in this study.*

The various layers were converted into raster before analysis. Roads were buffered at 50 meters from the road edge to find suitable areas along the roads. Population layers were created from the wards population data obtained from the District Population office. The population for each location was summed up to give the wards total population. Then reclassification was done after querying to identify those wards with a population of over 10,000 as a threshold for densely Populated wards. Land uses were also reclassified based on the council codes and those used in a study done by Tardos Zain (2009).

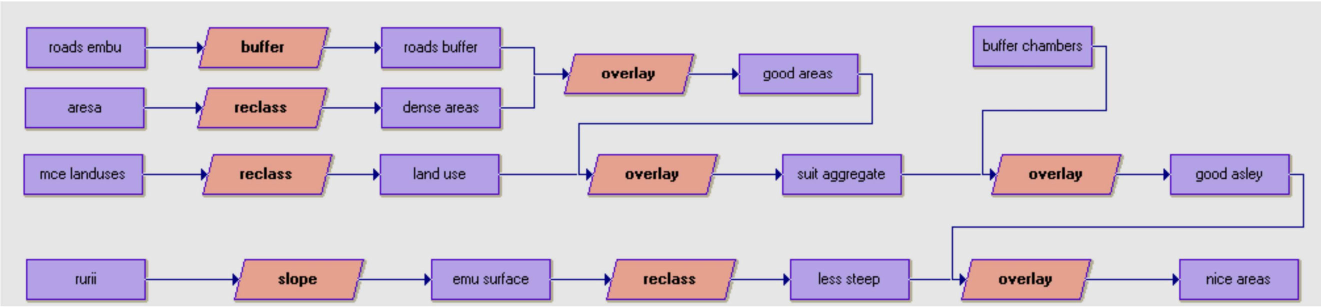


Figure 4. *Modeling and Analysis done with Idrisi Macro-modeler tool.*

5. Results and Discussions

On average, 31.74 tons of garbage was transported to the only open dumpsite some 15kilometres north East of Embu town on daily basis. The only garbage truck servicing the town is overwhelmed by the backlog of the refuse accumulating in many areas of the town. To facilitate waste collection, the council has built receptacles in the town center where all wastes from commercial, light industries and hotels is put before collection by the council's garbage truck (plate 2). The study found out that the existing waste management practices are labour-intensive, old fashioned and not anchored on any technology or innovation..

From the preliminary analysis, GIS was able to identify a total area of 0.40km^2 as land suitable for further consideration and evaluation. Further, 18.23km^2 of disaggregate plots in njukiiri, kamiu and matakari wards did not meet the Embu urban land use threshold and as such were regarded unsuitable. After site visitations, cross tabulation and evaluation was done using impact factors like the land value, Population density and Embu municipal Council by laws on land use and waste management. The GIS system search narrowed down to 0.15Km^2 of disaggregated plots spread across different wards in the municipality (table 1).

Table 1. *Results of cross tabulations and Evaluation for suitability Areas.*

Category	Meaning	Area (Km^2)	Wards
0	Unsuitable	18.23	Njukiiri, Kamiu, Matakari
1	Suitable	0.15	Kangaru, Blue Valley, Majengo, Itabua

The final suitable area stood at 0.15Km^2 a drop of an area of 0.25Km^2 from the initial land area of 0.40 Km^2. On the other hand, unsuitable areas increased from 17.98 Km^2 to 18.23 Km^2, gaining 0.25Km^2 of the land lost from the initial suitable land identified in the preliminary stage. This is attributed to the fact that some zones did not meet the Municipal Council of Embu economic and land use thresholds, were on steep slopes and fell within farm lands.

6. Conclusion

Utilization of spatial information technologies in the selection of potential sites for the construction of Waste Transfer Station in the Municipality of Embu considered bio-physical, social and environmental factors. Such GIS based approach provides evidenced- informed decision making where multiple variables are ranked and weighted on the basis of relative importance of factors used in applications such as suitability mapping.

Integrating GIS and GPS in the structuring of wastes management information through systematic collection, compiling and analysis will ensure creation of a waste related geo-database and continued updating of the municipal waste records. In a rapidly growing urban centre like Embu, a clean environment is envisaged to promote businesses, public health and investments as the facility will create employment and management the waste stream. To efficiently manage Municipal Solid Wastes (MSW) there is a need to encourage recovery of valuable resources from the waste stream before final disposal through segregation and use of organic composting facilities.

A waste transfer station seem to be a viable solution to the growing and urgent need for sustainable waste management techniques especially segregation and reduction. The adopted 70 tons per day capacity Transfer station is adequate given the current 31.74 tons waste load collected on daily basis within the expansive municipality of Embu. The work recommends more studies in the future on quantification and categorization of MSW from the municipality on a spatial and temporal scale given the rapid urban expansion of Embu town.

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