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GIS AND MFA APPROACH FOR SOLID WASTE MANAGEMENT TOWARDS INDIAN PROPOSED SMART-CITY

Jaydeep Lella, Venkata Ravibabu Mandla***
and
*Xuan Zhu****

ABSTRACT

Incessant population growth and urbanisation results in the growth of heaps of solid waste in the urban localities. Proper disposal and recovery techniques through solid waste management (SWM) are widely followed to have a control over the negative environmental implications. Life cycle assessment (LCA) can be a tool in reducing these environmental implications by solid waste and also helps in reducing the impacts on the environment from growing urbanisation. This work, solid waste management through MFA in LCA perspective and GIS is being observed in managing the municipal solid waste for a proposed smart city, Vellore. Various techniques like indices derivation from various satellite imageries help in estimating the vegetation change over from past years resulting in depletion rate of 2100m^2 area, optimal route analysis for a proper waste collection covering all the dispose points, reducing collection route by 59.12 per cent and various SWM techniques that result in proper solid waste management have been studied. These studies and techniques can be redefined based on localities perspective for their own waste management system throughout the Indian cities and for their smart cities planning.

Keywords: GIS Solid Waste Management, Life Cycle Assessment, Network Analysis NDVI, MFA.

*OS – GST Lab, Department of Environmental and Water Resources Engineering, School of Civil and Chemical Engineering (SCALE), VIT University, Vellore, India.
**Centre for Geoinformatics Applications in Rural Development (C-GARD), School of Science, Technology and Knowledge Systems, National Institute of Rural Development and Panchayati Raj (NIRD&PR), Hyderabad, India.
***School of Earth, Atmosphere, and Environment, Faculty of Science, Monash University, Clayton Campus, Clayton, VIC 3800, Australia.

Introduction

Urban municipal bodies in India generate more than 1,00,000 metric tonnes (MT) of waste every day.Metropolitan cities in India like Mumbai, Bengaluru, Chennai alone generate 7000 MT, 5000 MT and 5000 MT of waste, respectively (Urban Solid Waste Management in Indian Cities, 2015). Indian government proposals of smart cities have driven many technologies and ideas of solid waste management (SWM) into the urban localities (Smart Cities Mission Statement and Guidelines: 2015, Vellore Smart City Proposal: 2016).These smart cities initiation is leading to various infrastructural developments in physical, institutional, socio and economic factors.

According to National Institute of Urban Affairs (Urban Solid Waste Management in Indian Cities, 2015), key findings/challenges in Indian solid waste management are an improper collection of waste, waste accumulation along streets and roads, lack of proper processing and disposal system, the lesser involvement of stakeholders, environmentalists and technology providers.

Various government bodies like, United Nations Environment Programme (UNEP), Ministry of Environment and Forests (MoEF), Central Pollution Control Board (CPCB), State Pollution Control Board (SPCB) and National Solid Waste Association of India (NSWAI) are planning and developing various policies for an effective solid waste management in Indian SWM perspective. But due to major challenges and issues faced by these organisations from the generation phase of waste to disposal phase, new technologies and ideas are being encouraged and exchanged. Hence, this paper studies the present municipal solid waste management scenario of a proposed smart city and gives an effective and optimal solution based on life cycle assessment component, Material Flow Analysis integrated with GIS and remote sensing ideology.

Alternate energy is a promising source of conserving energy and reducing impacts on the environment. The proposed smart cities are majorly concentrating on the issues of solid waste management and energy alternatives. Recent changes in Indian rules on solid waste and other wastes have made authorities to give importance on SWM (Solid Waste Management Rules: 2016, Construction and Demolition Waste Management Rules Report: 2016, Plastic Waste Management Rules: 2016). Life cycle analysis helps in technical and policy analysis and GIS approach represents an innovative and useful decision support systems for minimising the challenges faced by the municipal authorities. In the present study, material flow analysis of municipal solid waste is observed for a ward scale of an urban local body which includes creation of spatial data of vectors used for modelling purpose in proposing an optimal route for transporting the waste and NDVI used in quantification of land area affected by the dumping of the municipal solid waste (MSW).

Literature Review

India is in midst of a profound transformation with an unprecedented rate of rapid urbanisation, increasing living standards and quality of life of people along with increasing energy consumption generating an energy crisis (Sainu et al,2017). This clearly indicates that the need for alternate energy is to be addressed and recommended to overcome the energy crisis. In this regard, alternate energy production through solid waste is a promising source for energy generation for the upcoming energy crisis. It is also noticeable that urban population has risen from 25.85 million in 1901 to 377.1 million in 2011, which is the growth of almost fifteen times, which points out that solid waste generation must have increased drastically. This gives a clear idea that if the solid waste management is done more efficiently, energy production by waste to energy techniques gives drastic production in energy.

Material flow analysis (MFA) and life cycle assessment (LCA) when combined together, large and complex SWM systems can be analysed with different environmental aspects. This study has shown reduction greenhouse gas (GHG) emissions when the residual waste stream is diverted with food waste. It also states that this type of studies are found to give potential results to provide policy and decision makers with valuable information about the environmental performance (David et al, 2016).

Network analysis in GIS system for the delivery of fresh vegetables reduced their deterioration and delivery time. This mode of analysis can be implemented for finding out the fastest route with lesser drive time to collect the solid waste from the known municipal locations. This also helps in reducing the GHG emissions as the optimal route can be found with lesser drive time rather than following the conventional route followed by the municipal people (Abousaeidi et al, 2016, Pedro et al,2017).

Vegetation change detection for Vellore district for the years 2001 and 2006 found that forest or shrub land and barren land cover types have decreased about 6 per cent and 23 per cent in the year 2001 and 2006, respectively, agricultural land, water and built-up have increased by about 19 per cent, 7 per cent and 4 per cent (Gandhi et al, 2015). In this context, vegetation cover change can be estimated in and around the municipal dumping sites to have a check over the environmental degradation around the dump sites.

The cost of municipal waste collection can be reduced when an optimised municipal solid waste collection system is implemented along with transfer stations (Khanh et al, 2017, Son et al, 2016). This optimisation of routes can give different models for different municipal conditions along with reducing the GHG emissions (Joel et al, 2014, Jose et al, 2014, Zdena et al, 2013 and Kinobe et al, 2015).

A comparative analysis conducted by Julian Cleary (Julian C, 2009) on LCA of MSW indicates that there are many benefits generated through recycling rather than the landfilling of waste or thermal treatment to produce energy. The study also states that the common life cycle stages of MSW include (1) Collection; (2) Transportation; (3) Sorting; (4) Transportation to a treatment facility and (5) Treatment. Keeping this in mind, our study on MSW by LCA and GIS can be done very sophisticatedly implementing all these life cycle phases and giving a solution for an effective SWM.

Study by Tapas Kumar Ghatak (Tapas K G, 2016) on unaddressed issues of MSWM in India found collection of unsegregated waste under contractual management, segregation after collection by rag pickers instead of ULB management involvement, waste reaching the landfill site or dumpsite through a complex route which is generally untracked path, all these issues are to be resolved and require proper SWM system.

Methodology

For this study of LCA integrated GIS approach in SWM, the study area is identified which has to be a smart city with challenges faced by the municipal authorities in solid waste management, then the initial idea on methodology is framed through which data have been acquired from various sources for further study.

Study Area : The present study is carried out in Vellore municipal city, situated in the Indian State of Tamil Nadu. Located at 12.9165oN Latitude and 79.1325oE Longitude. In the year 2016-2017, Vellore has been proposed to be one of the smart cities to be developed in India. Government authorities are finding out various new technologies to improve the city in the green and clean way in the smarter direction. The city is divided into 4 major zones and 60 wards. Until the proposal of a smart city, there wasn't any waste treatment or recovery process for the municipal waste collected in the city. Hence the present study has been decided to carry out in the Vellore municipal city for proposing a better SWM solution along with the waste management that they are following till date. Following figure 1 gives an idea of the location of the study area.

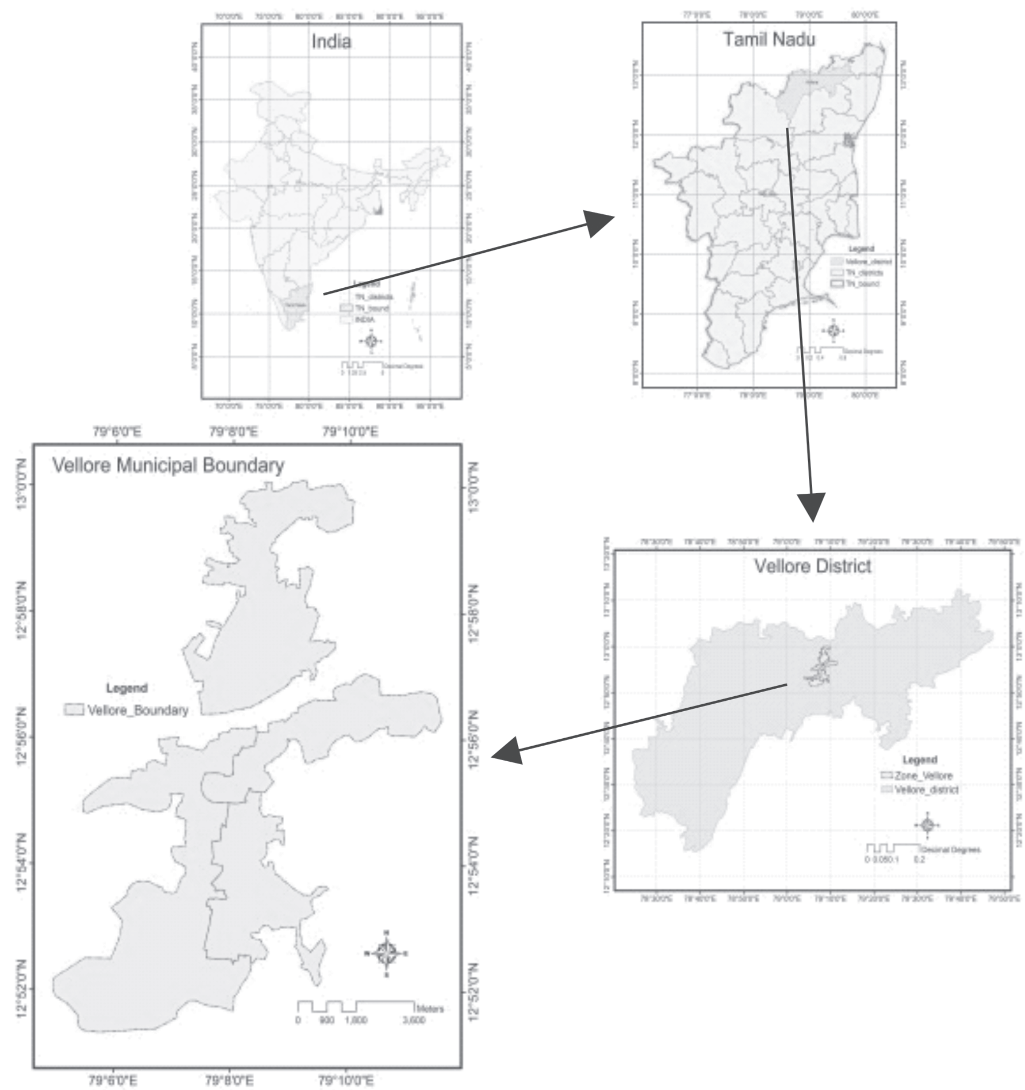

Figure 1: Study Area: Vellore City Municipal Corporation

The present study is on solid waste management which is achieved by integrating life cycle assessment (LCA) approach for Material Flow Analysis (MFA), Geographical Information Systems (GIS) and remote sensing. As discussed earlier, LCA for SWM is done in different life cycle stages of collection, transportation sorting and treatment. All these have to be assessed and given an optimum solution to achieve proper SWM. A collection of LCA inventory data to give an overall waste material flow in the collected waste from the residential areas (municipal waste) which constitutes production phase, usage phase and end of life phase of MSW is carried out to bring a Material Flow Analysis model. Proper spatial data is required to analyse optimal route for waste collection, the proposal of the transfer station. Hence, the municipal boundaries of the study area are required. These spatial vectors are created using field visits and surveys as well as using GIS software like ArcGIS, QGIS. These vector data are used to conduct network analysis for optimal routing. Spatial data from landsat legacy are used to quantify the environment degraded around the dump sites which can be used for new policy making and take required measures to have a check over the environment. NDVI is performed for the buffer regions of the dumpsites in a time series and the area of land degradation is extracted from the past years using the standard NDVI values for various land cover classes. For the optimal routing to be followed by the municipal people, navigation details of the optimal route are provided which can be adapted from time to time based on restrictions and traffic details implemented by the transport department. The above methods are combined together to achieve a sustainable and promising method of solution in implementing efficient SWM for the study area shown in Figure 2.

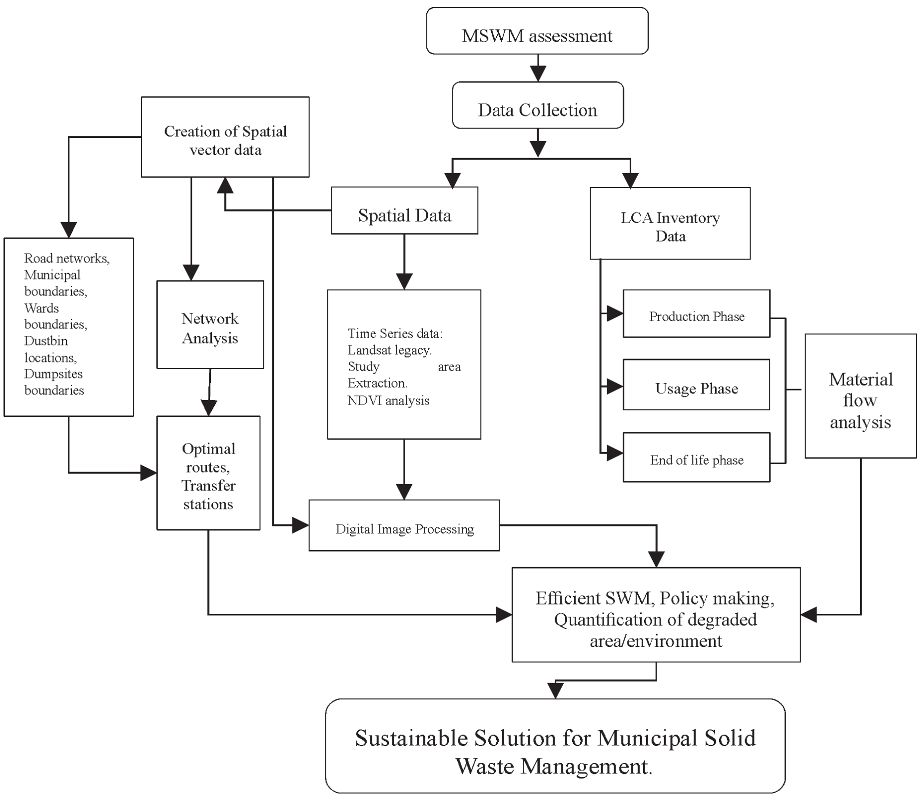

Figure 2: Methodology Followed in Present Study

Spatial vector data are created using GPS, navigation tools as well as GIS software packages overlying the google maps. Municipal boundaries, zone boundaries and various other locations have been created using above mentioned tools.

For the material flow analysis of waste materials, various datasets have been collected from the local municipal authorities.Transparency and data unavailability issues led to inconstant data provision, constant data available have been collected and the analysis has been performed, the same can be achieved for large scale of the whole study area if the data are readily available. Department of Municipal Corporation, composting units, national associations and transport department provided data for the present study.

Then for the quantification of the vegetation cover change, satellite data have been obtained from U.S. Geological Survey (USGS) website.The satellites used in this study include LANDSAT series (TM,ETM+ and OLI/TIRS).These satellites cover the land cover of the earth routinely so that continuous study and observation from this satellite can be achieved. In order to study the vegetation cover change for past 15 years, on a 5-year gap basis, the data have been acquired from the year 2000 to 2017. Other field data were obtained from various government municipal authorities which were combined with GIS platform and material flow analysis to obtain efficient results. Street and road data are obtained from transport department. Municipal waste-related data are obtained from garbage composting units of Vellore. The acquired data details have been shown in the following Table 1.

Table 1: Data Acquired from Various Sources

Satellite Data: US Geological Survey					
S. No.	Satellite Resolution	Spatial Acquisition	Date of	Bands Used	
1.	Landsat 7	30 m	12.05.2000	Band 3 (Red)	Band 4 (Near Infrared)
2.	Landsat 5	30 m	18.05.2005	Band 3 (Red)	Band 4 (Near Infrared)
3.	Landsat 5	30 m	01.06.2010	Band 3 (Red)	Band 4 (Near Infrared)
4.	Landsat 8	30 m	28.02.2017	Band 4 (Red)	Band 5 (Near Infrared)

Field data: Vellore Municipal Departments			
S.No.	Department	Data Obtained	Date of Acquisition
1.	Garbage Composting Centre, Vellore Municipal Corporation	Waste collection and transportation details, types of waste, handling and processing details	16.02.2017
2.	Transport Department, Vellore Municipal Corporation	Streets and roads details	03.03.2017

Life Cycle Assessment (LCA): Material Flow Analysis (MFA)

Life cycle assessment is an accounting tool which takes all the resource inputs and then assesses the impacts and emissions caused by product and service until its lifetime (Kaufman S M, 2012).

LCA is a quantitative methodology to assess the sustainability of human activities where material flow analysis is about determining and identifying the flow of material in a process chain, MFA computes mass balance between inputs and outputs. MFA is a component of LCA where it helps the LCA of waste materials with an in-depth assessment. There are very few studies where MFA inducted LCA has been done. Hence, this study inherited this type of methodology where the combination of MFA type LCA integrated with GIS and remote sensing was implemented for solid waste management.

LCA Database: Life Cycle Inventory (LCA): From various LCA variants, the cradle-to-grave approach is identified to be focused in the present study, used to assess the flow of waste materials from the generation stage to the disposal stage. Life cycle inventory (LCI) is to be developed for performing the LCA. Federation of Indian Chambers of Commerce and Industry (FICCI) has been working to bring an importance on this life cycle thing in Indian stakeholders and to develop inventory database for LCA (Environmental Management-LCA-Requirements and Guidelines, 2009, India LCA Directory, 2014). For the present study of MFA, due to transparency and unavailability of data issues, required information is obtained from concerned authorities and annual reports of various ministries.

Vellore Municipal Corporation is divided into 60 wards, present MFA is being performed for wards 9 and 12. Area of these wards 9 and 12 are 1159778 m2 and 644357 m2, respectively. Table 2 gives the inventory data that have been incorporated for analysing the MFA.

Table 2: Life Cycle Inventory: Vellore Municipal Corporation and State Annual Status Reports

Name of Corporation	MSW collection method	Segregation details	MSW storage	Processing of MSW	Type of disposal
Vellore	House to house	36 compost units	HDPE bins-312	Composting, recycle and reuse	Open dumping
Wards	MSW generated TPD	MSW collected TPD	MSW Treated	MSW disposed TPD	
9 and 12	5	4.5 – 5	3.8	1.2	

Inventory (Wards 9 & 12)	Details
Total waste generated per day	4 to 5 tonnes
Mode of collection	Tricycle
Tricycle number	12
Collection vehicle capacity (Kg/tricycle)	200
Manpower required for collection	24
Compost generated	1.5 tonnes per 5 tonnes of waste
Cost of compost (Rupees per pack)	10
Plastic generation (Kg/week)	50
Number of plastic crushers per compost unit	1
Plastic resale value (Rupees per kg)	1 for resale and 20 for road construction
Number of houses covered per day	~2000
Material of waste (Wards 9 and 12)	Quantity (Kg/day)
Food waste	700
Paper waste	1700
Cardboards	350
Plastics	250
Textiles	100
Rubber	25
Leather	25
Garden trimmings	600
Wood	100
Miscellaneous organics	100
Glass	400
Metal	300
Non-ferrous metals	50
Ferrous Metals	100
Dirt, ashes and bricks	200

Source: Annual Report of SWM in Tamil Nadu, 2015, Manual in MSWM, 2000, CPHEEO reports, 2005&16.

MFA Model

MFA model is constructed using STAN 2.5 freeware software with available LCI, STAN stands for substance flow analysis (Jeroen B G, 2002). This freeware is used to build a graphical model of MFA for the wards 9 and 12, with their solid waste materials from generation phase and their handling and disposal details.

The model is constructed by dividing the flow into three major divisions; Collection phase, usage/handling phase and disposal phase. Each phase is given details of processes involved in them and their type of process is explained in detail. Each phase is divided into sub-system defining their internal process involved, suppose, in the collection phase, the sub-system is created to give the details of each material quantity collected every day and was computed to an average collection of that type of material for the year. In the same way, usage phase and disposal phase are sub-divided to give their own internal processes. Usage and handling phase includes composting, recycling, crumbling processes. Disposal phase includes resale and reuse, the sale of compost, dumping processes. Their quantities and processes are incorporated in detail to bring out the yearly outcomes of each process and quantity of waste being generated, processed and disposed of are observed.

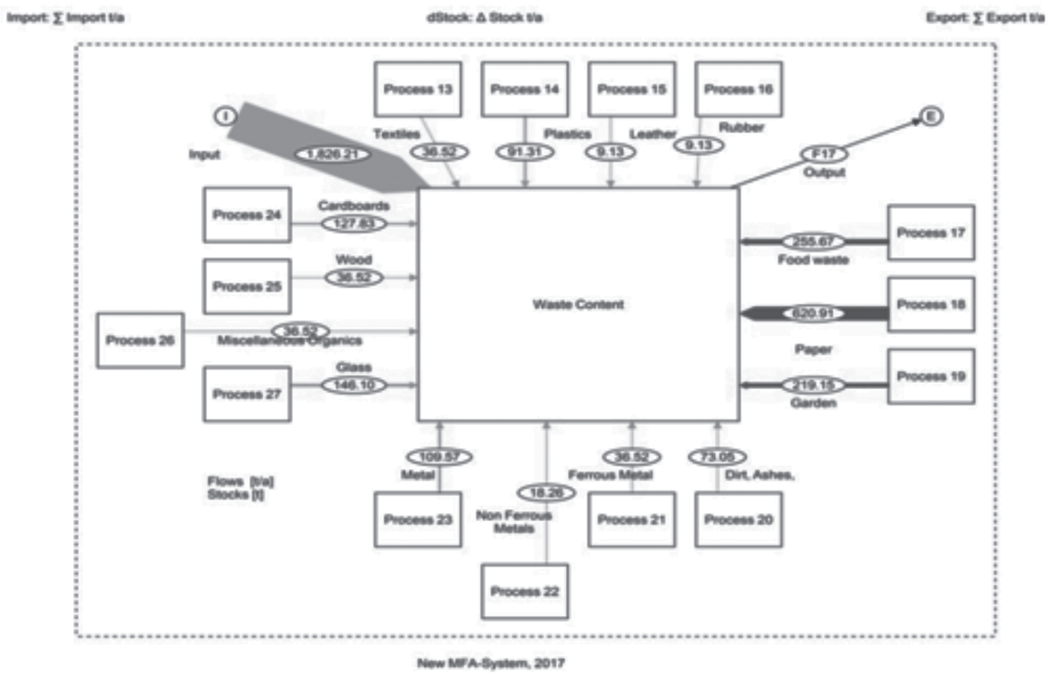

Figure 3: MFA Model for MSW Flow in Wards 9 and 12 of VMC

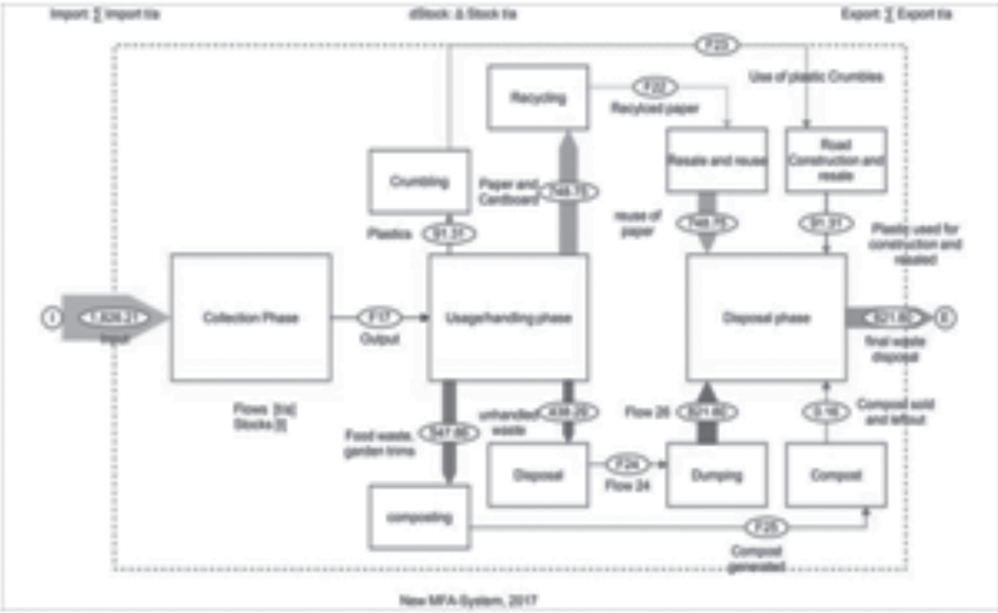

Figure 4: MFA Subset Model of Collection Phase

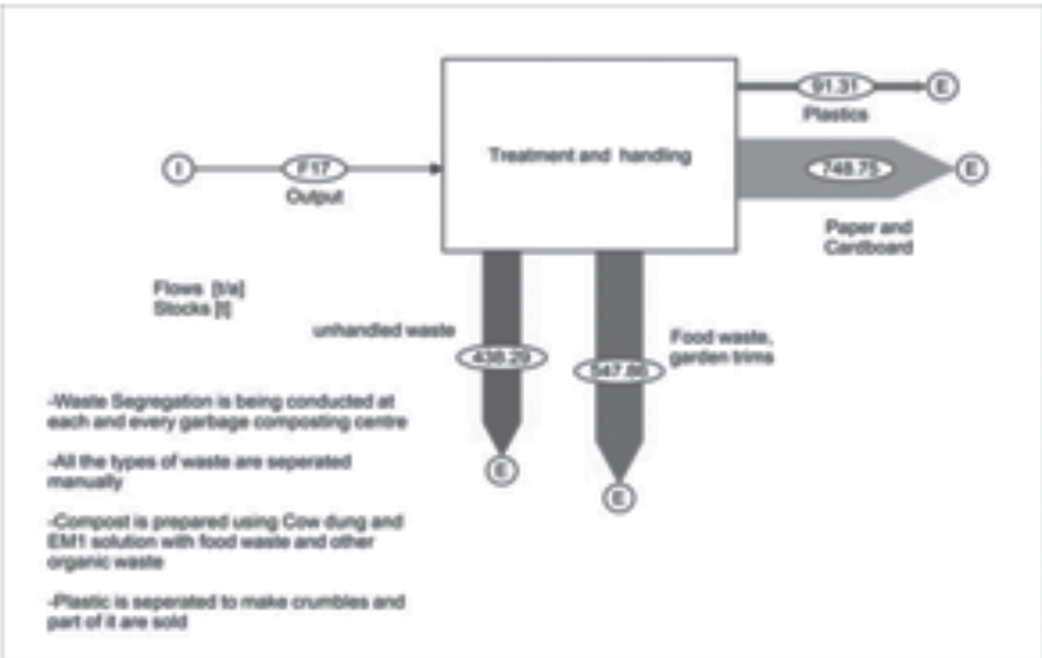

Figure 5: MFA Subset Model of Usage and Handling Phase

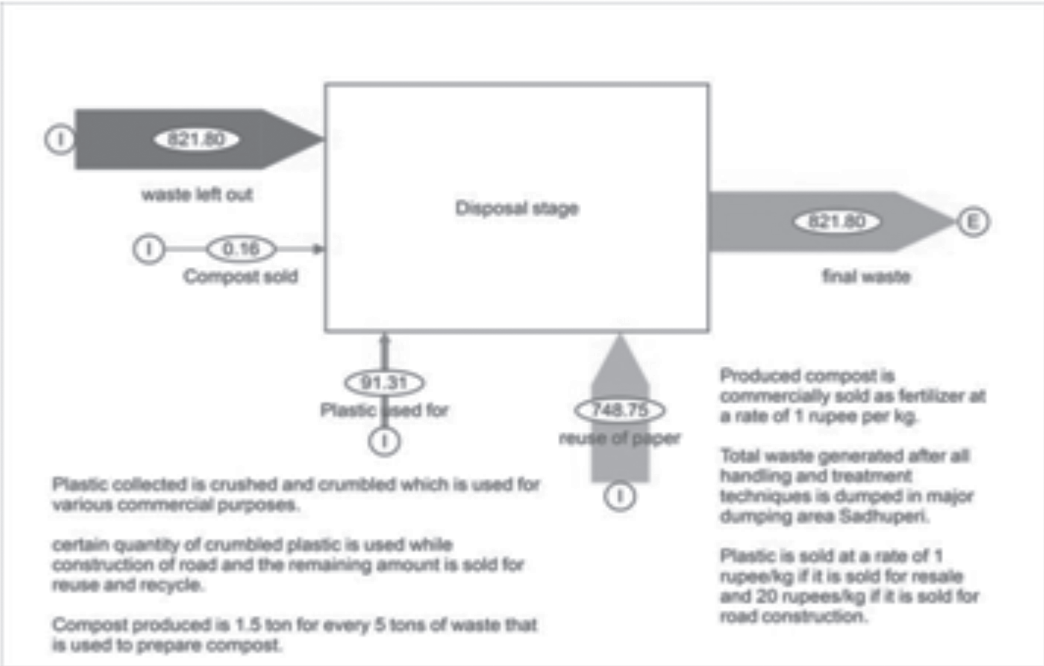

Figure 6: MFA Subset Model of Disposal Phase

The above MFA package is created only for the wards 9 & 12 of Vellore Municipal Corporation, this can be performed for the whole of Vellore Municipal Corporation as well as for any other MSWMS if the data are available and transparency is not a factor of the issue.

Results Outline:

- In the wards of 9 & 12 of the Municipal Corporation, on an average, about 1826.21 tonnes of waste is generated every year.
- Out of 1826.21 tonnes, approximately 821.80 tonnes of waste is being dumped openly without any treatment.
- MFA analysed can be modified anytime for any waste and the exact amount of waste flow can be calculated.
- This can be extended for any other treatment included in future SWM techniques.

GIS and Remote Sensing Approach for SWM

For the present study of SWM system in Vellore Municipal Corporation, various vectors are needed to be designed so that, using these vectors proper collection methods, transfer stations, optimal routes can be assessed and propose a better and efficient SWM.

All the type of roads in the Vellore city municipal corporation have been covered and those in inaccessible areas have been created using Google maps in ArcGIS software. Point vectors have been created for all the dustbin locations in the city and line vectors with vertices as road ends have been created for road networks. Other vectors include municipal boundary, zonal boundaries, ward boundaries and dumpsites boundaries.

Various buffering measurement functions are used to calculate distance and areas from the defined vectors to quantify the environment. Network analysis functions are used to provide optimum collection routes of solid waste in the municipality. Various geometric measurement functions are used to locate the optimal place for transfer stations.

Study of Waste Collection Method: Before 2015, Vellore Municipal Corporation used to follow, curbside or alley pick up method of collecting the MSW, where the municipal waste collection crew comes in transporting vehicles and collect the wastes from HDPE bins placed on the curbside. Major issues like a mix-up of waste and accumulation of waste along the roadside made the authorities a challenging task in the collection of waste. After 2015, garbage composting units came into a corporation which made authorities to collect the waste door to door by entering the waste generator house premises, this method is called to be backyard method.

Backyard method gave optimum results like a separate collection of waste without mix-up of materials, segregation of waste made easy to the collection crew but this approach of backyard method is costliest.

Proposal of Transfer Station: Transfer station for collecting the solid waste generated by proposed smart city is found by the median center method, where the Euclidean distance of the dustbin location of each zone is minimised (Xuan Zhu, 2016) so that the transfer station is well routed and nearer to all the collecting vehicles to reach the transfer station in lesser drive time. Other planning and design factors are considered for this transfer station facility, type of transfer station is to be direct discharge transfer station, where the collection vehicles dump the collected waste to be processed and transferred to landfill sites, location of the transfer station is to be far from the residential areas with huge open land availability, it has to be easily reached from all the composting units/dustbin locations, transfer means is by motor vehicle transport by using tractor trailer which is commonly used by the municipal authorities, sanitation and environmental requirements are to be focused with enclosed facility with no accumulation of waste around.

As discussed earlier, about curbside or alley pick up collection method and backyard method of collecting the waste, transfer station proposal was taken place for both of these collection methods, so that it gives the municipal authorities an idea of site selection for any type of collection method they follow (Figure 7).

By minimising the Euclidean distance of road network for backyard method and dustbin points for curbside method, transfer station site location is allocated along with the design factors considered. Following Tables 3 and 4 give the location details of proposed transfer stations for each zone in the Vellore Municipality.

Table 3: Transfer Station Location Details for Curbside Collection Model

S.No.	Zone	Latitude	Longitude
1	Zone 1	79° 8' 25.6"N	12° 57' 27.39"E
2	Zone 2	79° 9' 25.73" N	12° 56' 6.13" E
3	Zone 3	79° 8' 13.77" N	12° 54' 22.73" E
4	Zone 4	79° 7' 24.9" N	12° 54' 29.83" E

Table 4: Transfer Station Location Details for Backyard Collection Model

S. No.	Zone	Latitude	Longitude
1	Zone 1	79° 8' 23.78" N	12° 57' 45.32" E
2	Zone 2	79° 9' 31.55" N	12° 56' 6.74" E
3	Zone 3	79° 8' 15.71" N	12° 53' 50.83" E
4	Zone 4	79° 7' 16.27" N	12° 53' 47.59" E

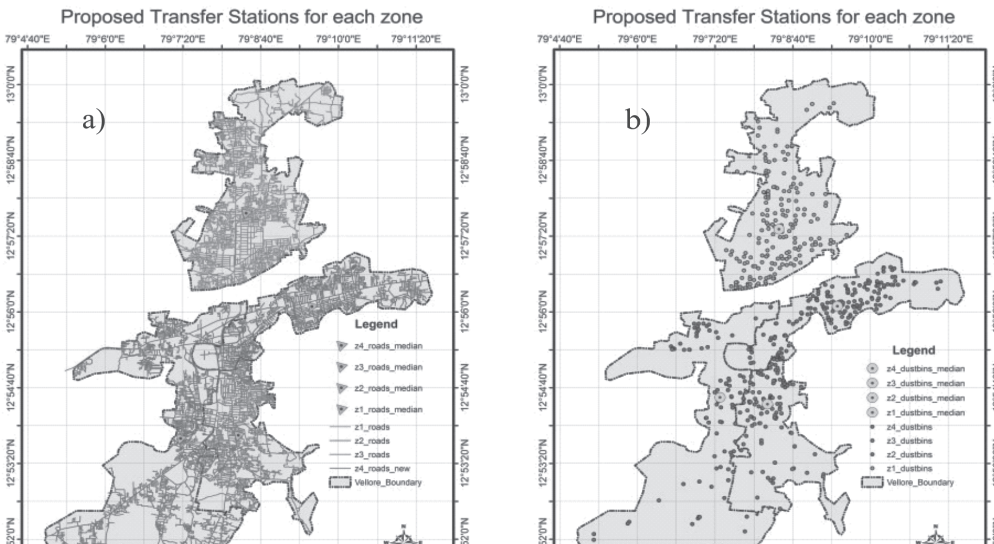

Figure 7: Location of Proposed Transfer Stations for Both Collection Methods, a) Backyard Method b) Curbside Method

Network Analysis: Movement of any materials, goods, supplies, water supply and much more can be analysed using network analysis tool. This tool can be used to find the shortest path, optimal route reducing the travel time, distance, cost and many other functions. In our study, we use network analysis to determine the total optimal route for the collection of waste following the various dustbin locations in the city. The spatial vector data of roads created are used for this study.

The optimal route is found for each zone (1, 2, 3 and 4) using network analyst. Each zone road network is divided and then the feature class is created for the road network of that zone converting all the line features by splitting at their intersections. This enabled the turn feature to be set in the road network. Road network data set is created from Arc Catalog with defined turns features and junctions of the road network. After creating the network dataset, route analysis is performed by allocating the stop locations at dustbin locations for the waste collecting vehicle as shown in Figure 8.

The same model continued for different zones and words, once the analysis is performed for all the zones and wards following results are obtained as shown in Figure 9, Zone 1 optimal route is covering about 186 dustbins with 49.9 kilometers of route, zone 2 optimal route is covering about 175 dustbins with 37 kilometers of road network, zone 3 is covering about 121 dustbin stops with 29.6 kilometers as optimal route and zone 4 is covering about 92 dustbin stops with 31.6 kilometers as optimal route.

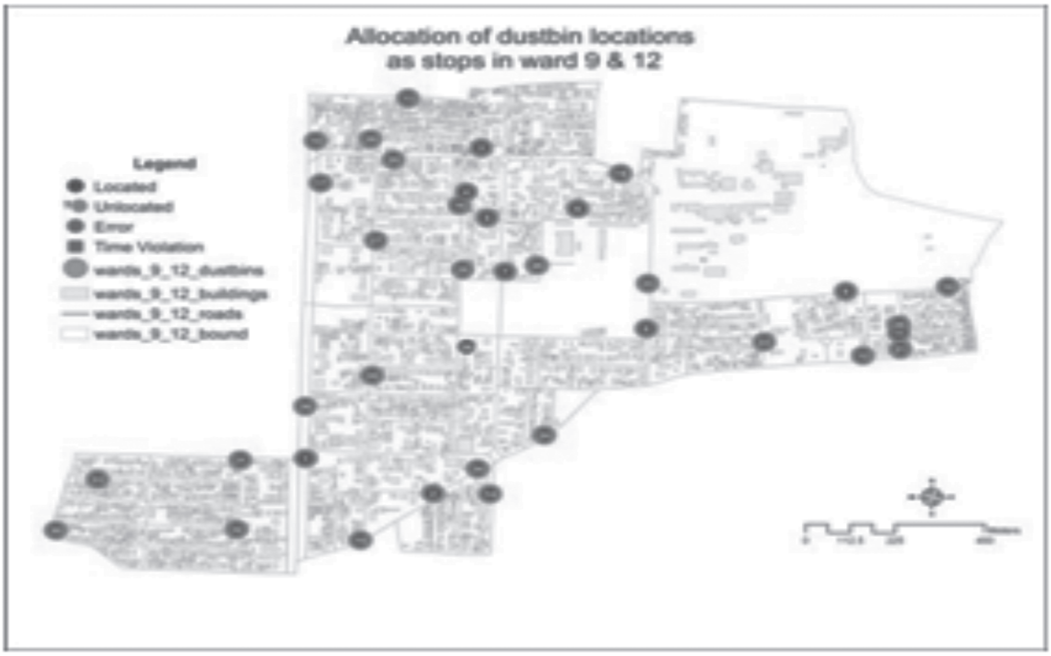

Figure 8: Dustbins Allocation as Stops in Route Analysis for Wards 9 and 12

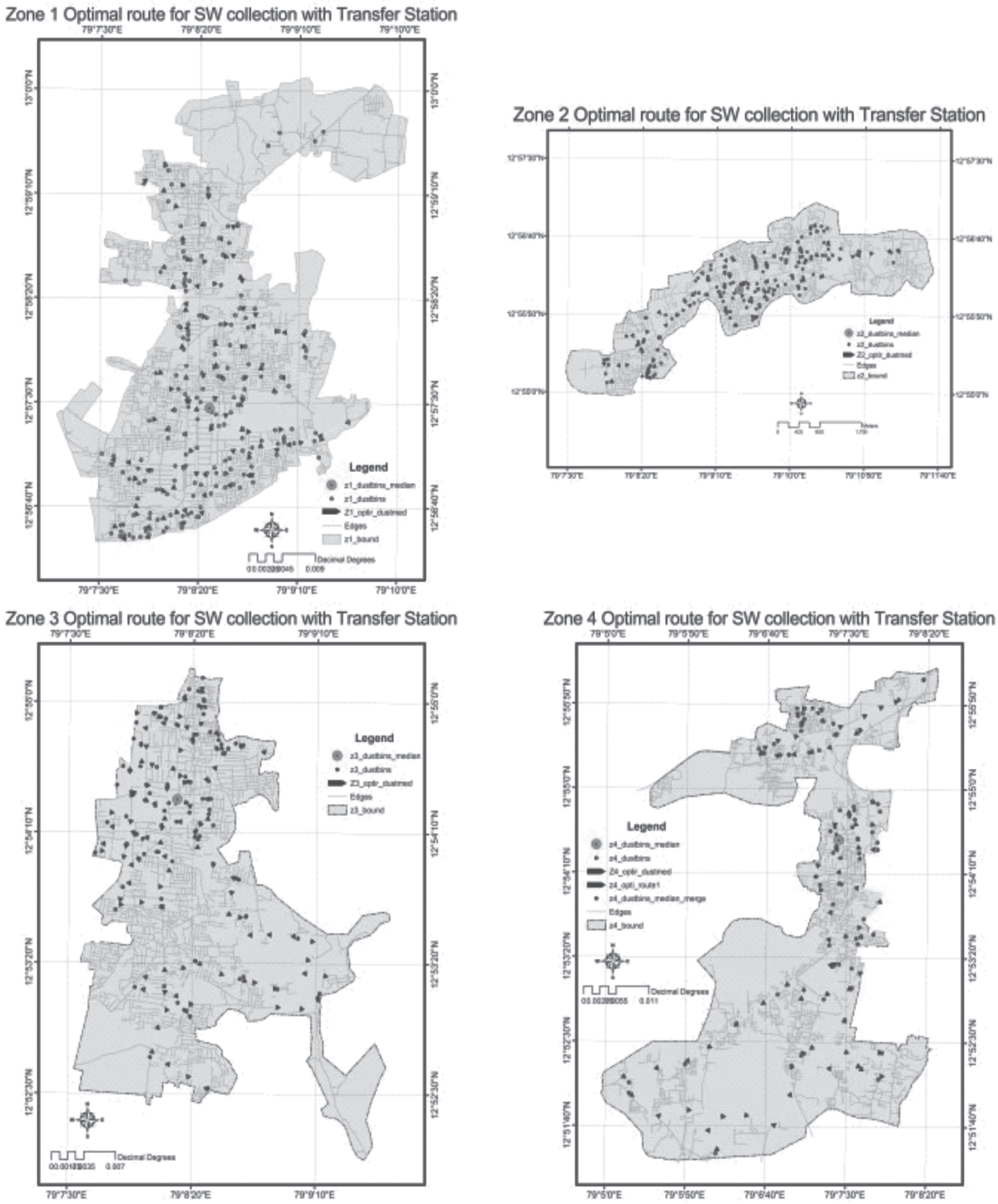

Figure 9: Optimal Route for SW Collection of Zones 1, 2, 3 and 4

The same is done for wards 9 & 12 with and without road restrictions, the digitized direction of the road was changed and then the optimal route is found again to give an accurate real-time routes for collection of waste, 12.26 kilometers of optimal route with road restrictions covers all the 35 dustbin locations whereas 10.3 kilometers of optimal route is achieved without road and traffic restrictions covering all the 35 dustbin locations as shown in Figure 10.

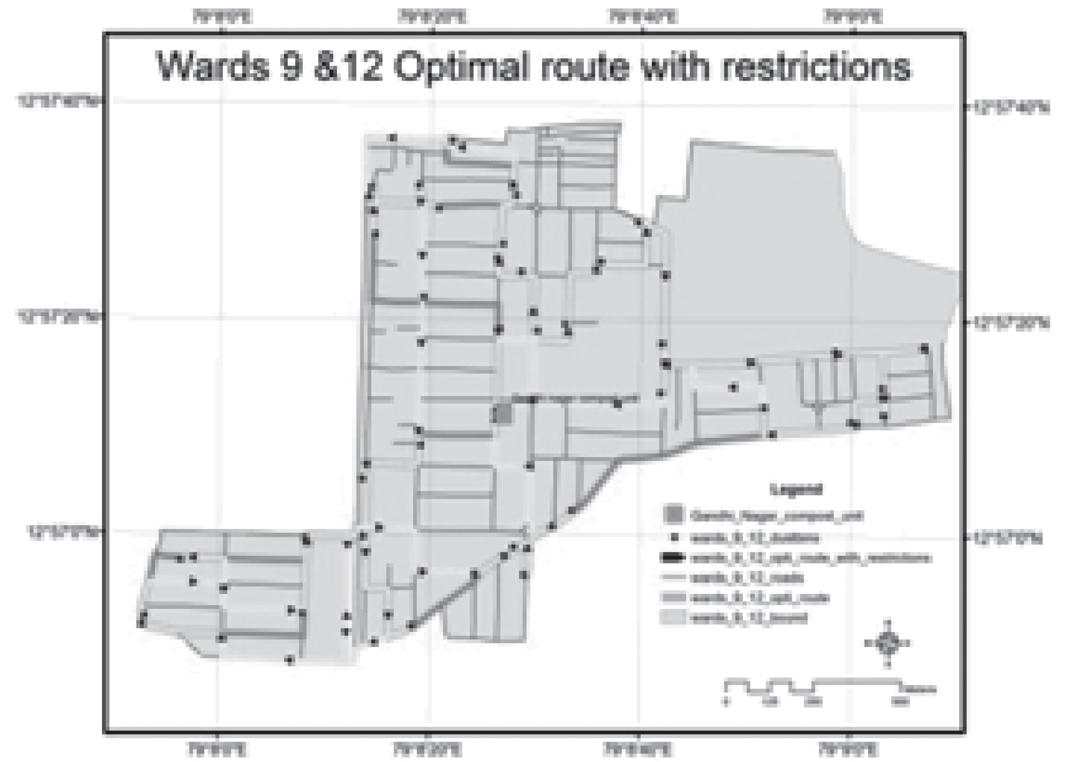

Figure 10: Optimal Route for SW Collection of Wards 9 and 12 with Road Restrictions

The same network analysis has been performed to determine the shortest route in transporting the waste from transfer station of each zone to Sadhuperi dumpsite as shown in Figure 11.

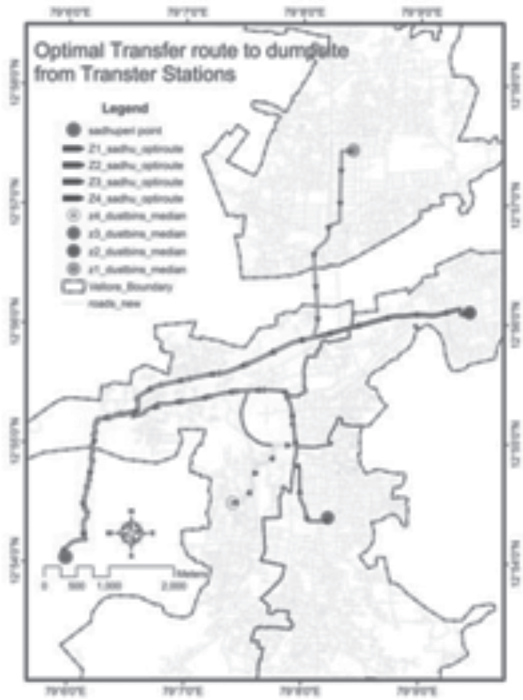

Figure 11: Optimal Route to Dumpsite from Transfer Stations

These optimal routes are combined with street information data obtained from transport department to give navigation details for driving crew. Table 5 gives the navigation details of driving directions from zone 1 to Sadhuperi dumpsite.

Table 5: Navigation Details on Optimal Route from Zone 1 Transfer Station to the Sadhuperi Dumpsite

S. No.	Direction	Drive
1.	Start at Location 2	
2.	Go west on 5th east cross road toward 2nd east main road	184.2 m
3.	Turn left on 2nd east main road	816.2 m
4.	Continue on Gandhi nagar municipal colony	274.3 m
5.	Turn right on kangeyanellur road	183.6 m
6.	Turn left on velloor chittoor salai	137.5 m
7.	Continue on polar salai	0.6 m
8.	Bear right on anna bridge road	1264.2 m

(Contd........)

Table 5 (Contd.....)

S. No.	Direction	Drive
9.	Continue on palathoram st (new katpadi road)	406.8 m
10.	Turn right on NH 46	2940.9 m
11.	Turn left on Anjaneyar Koil Street and immediately turn right on Anjaneyar Koil Street	66.3 m
12.	Continue on Rahim Sayub Street	503.1 m
13.	Turn left on New Byepass Road and immediately turn right on Erikarai Turn (Devi Nagar)	314.6 m
14.	Turn left to stay on Erikarai Turn (Devi Nagar)	2384.1 m
15.	Finish at Location 1, on the left	

Normalised Difference Vegetation Index (NDVI) Analysis: Land cover is depleting very drastically, in India, accumulation of waste is higher around the dumpsites.This accumulation of various types of waste is changing the land cover and depleting vegetation cover in higher areas.These changes of land cover especially vegetation cover are quantified in this study from the year 2000 to 2017.

In remote sensing, there are various indices which are used in extracting the land cover that is required, these indices are empirical relations formulated by many researchers helping in analysing the satellite data (Khalid et al, 2016). Normalised difference vegetation index (NDVI) is used to measure and extract the vegetation cover from various satellite imageries (eq 1).

$$NDVI = \frac{(NIR - red)}{(NIR + red)} \text{ ----- Eq (1)}$$

Where NIR: Near infrared region and Red: red wavelength band

To performing the NDVI analysis, buffer regions around the created vectors of dumpsites have been created with a radius of 500m to check the vegetation cover change in that buffer regions (Figure 12). These are three dumpsites, Sadhuperi municipal dumping site, this is an open dumping site where no treatment of waste is being conducted and it is a government authorised dumping site, Kalinjur lake dump and Gopal Samuthram dump area are also open dumping sites, but these are unauthorised dumping sites.

The study is extended focusing on major dumpsite of the Vellore Municipality, i.e. Sadhuperi dumpsite and quantifying the vegetation cover depletion from 2000 to 2017 (Figure 13). This study shows how the rate of vegetation cover is depleted in that dumpsite and can give the rate of change of vegetation cover every year and can predict the future depletions.

Image processing analysis is performed to estimate the vegetation cover around the dumpsites (Figure 12), NIR and red bands from satellite imageries are used to perform the NDVI image processing analysis. These bands are clipped using the region of interest as dumpsites with buffer region of 500m.

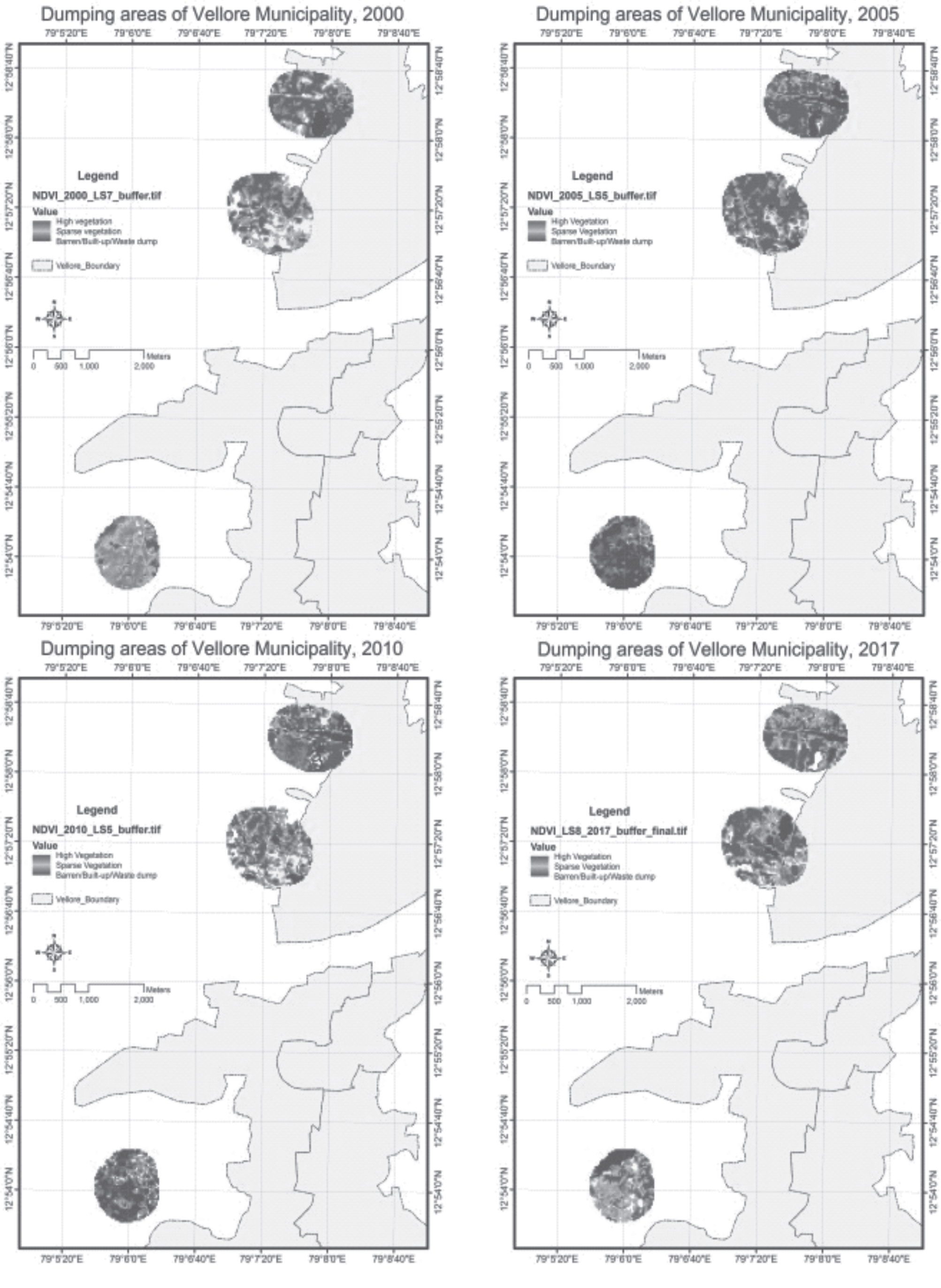

Figure 12: Optimal Route to Dumpsite from Transfer Stations

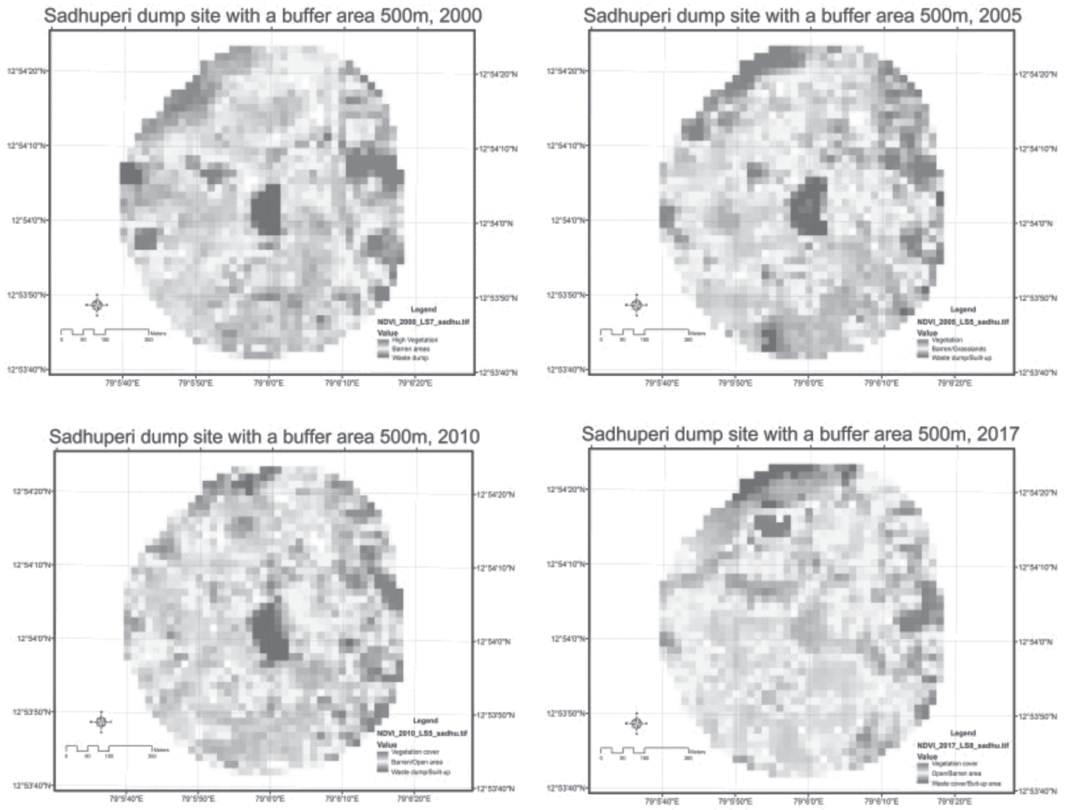

Figure 13: Optimal Route to Dumpsite from Transfer Stations

NDVI values result to exist between +1.0 and -1.0. Higher NDVI values range of approximately, 0.6 to 0.9 correspond to dense vegetation, moderate NDVI values like 02 to 0.5 may result in shrubs and grasslands whereas low NDVI values below 0.1 resemble areas of rock, sand and snow. For this study higher NDVI values are considered to estimate the number of pixels lying in that region to find out the area based on the spatial resolution of the satellite imagery (Table 6, Figure 14).

Table 6: Navigation Details on Optimal Route from Zone 1 Transfer Station to the Sadhuperi Dumpsite

S. No.	Year	High NDVI value pixel count	Area of vegetation under High NDVI value (m2)
		Vegetation area around three dumpsites	
1.	2000	376	338400
2.	2005	642	577800
3.	2010	245	220500
4.	2017	204	183600
		Vegetation area around Sadhuperi dumpsite	
1.	2000	75	67500
2.	2005	89	80100
3.	2010	83	74700
4.	2017	40	36000

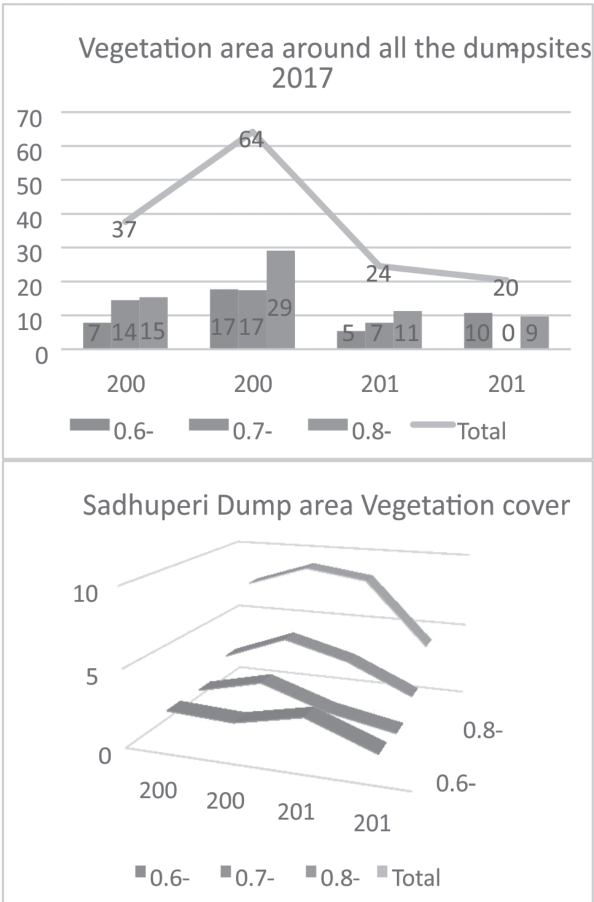

Figure 14: Vegetation Cover Change from the Year 2000 – 2017

Results and Discussion

SWM is efficient if the proper collection, segregation and processing are done. For the purpose, this approach of GIS in SWM is implemented so that proper collection of waste which is comfortable to the waste collecting crew is achieved as well as reducing the vehicular emissions through optimal analysis.

It is noted from the wards 9 & 12 sanitary officers that the route covered in a day in both wards for the collection of waste is about 25 to 30 kilometers now after optimal route analysis, it is shown that in 12.264 kilometers of the route the same can be collected. This method can be implemented for all the wards of the municipality thus reducing the collection time and other dependent factors.

Proposed transfer stations help in collecting the waste from each zone and further treatment and handling techniques can be implemented in these locations. This method of SWM can be implemented in each and every ULB if the data are available and maintained by the government authorities.

NDVI analysis performed for the quantification of vegetation covers represent the vegetation degraded from 2000 to 2017. This vegetation cover change is representation for estimation purpose. It is not solely responsible due to solid waste dumping and leachate deposition, there must be many other factors like unavailability of water, lower groundwater table, etc.

Conclusion

As stated and discussed earlier, material flow analysis is a component of LCA, where it gives flow analysis from the generation stage to the disposal stage. In this study, this MFA is performed manually from the data obtained from municipal authorities as well as using STAN 2.5 MFA software package which gave accurate results of overall yearly waste generation and its flow into different processing stages and finally gives total waste to be dumped in the landfill site/dumping site.

This type of analysis can help practitioners and policymakers to implement new limitations and amendments to give a proper SWM solution. This analysis helps various government bodies and stakeholders to involve into the issues of waste materials and provide a quick solution of SWM. This provides an accurate method of the quantity of waste flowing in each and every handling and processing stage. Every stage of SWM like generation, composition, segregation, treatment, economic factors and disposal quantities can be known and evaluated very efficiently.

Out of 1826.21 tonnes of waste generated, approximately 821.80 tonnes of waste is being dumped openly without any treatment. This shows that about 45.003 per cent of waste is still being dumped without treatment.

Network analysis performed in this work is for finding the optimal route in the collection of waste from various dustbin locations in the city. It reduces the travel time, more efficient collection of waste from disposing areas/dustbin locations. It also provides navigation details for the collection crew so that it makes them easier to collect the waste from the generators. This also helps the various municipal departments like garbage management committee, transport department to do the SWM in an economic point of view and plan accordingly to get optimum results in every field managing this municipal solid waste.

Sanitary Department of Vellore Municipal Corporation states that for the collection of waste in wards 9 & 12 it takes around 25 – 30 kilometres in two shifts of the day to collect the total waste of the wards. After calculating the optimal route by curbside collection method, it is found that only 12.264 kilometres of the route must be covered every day for waste collection. This reduces 59.12 per cent of route network to be collected. This optimal routing also helps in reducing vehicular emissions as well as fuel consumption costs.

This quantification of vegetation cover is performed which gives an idea that this type of analysis could keep a check over our environment and its dynamic changing patterns. In this way, an environmentalist can make his own research in the field of ecology for quantifying the change in the environment.

From this study, it is found that about 45.74 per cent of vegetation cover changed from 2000 to 2017. These type of studies help policy makers and practitioners to propose and redefine the regulations. The vegetation cover change rate is found to be 2100 m2 area of depletion every year around the dumpsite. If this is the case, 17 years from here approximately the area around the dumpsite become a barren land without any vegetation cover.

This model can be implemented in most of the rural bodies in India, As part of rural employability objective, these wastes from the nearby cities can be rerouted to nearby rural areas where the sorting and separation can be undertaken for sustainable reuse and recycle under the control of rural bodies through the above mentioned techniques. This process can involve rural people to create and monitor waste models which eventually could lead them to earn from the waste. These actions can reduce the waste quantities and help in reuse and recycle as well as create awareness in rural development and employability creation.

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