Research article Available online www.ijsrr.org ISSN: 2279–0543

International Journal of Scientific Research and Reviews

State-of-the-art Review: Solid Waste Management with Advanced Computational Technologies

Rubul Kumar Bania

[1]Department of Computer Applications, North-Eastern Hill University, Tura Campus, Meghalaya-794002, India

ABSTRACT

Due to the rapid increase in urbanization, industrialization and population, solid waste management (SWM) system is emerging as a big challenging problem for the urban development agencies in our country. Generation rate of municipal solid wastes in different Indian cities and towns are also increased. Mismanagement of municipal solid waste can cause adverse environmental impacts, public health risk and other socio-economic problem. Moreover, waste management system in many of the countries throughout the globe including our nation is still following the traditional complicated manual system for which large amount money is spent every year. Therefore, there is high demand for a robust SWM system, where an authority or agencies can get information right from filling of garbage bins, picking up of bins by the waste collecting vehicles and movement of those vehicles to the waste processing sites to landfill dumping sites. In this article an introduction to SWM system followed by reviews of the state-of-the-art recent utilization of science of information and computational based technologies in SWM systems are outlined in India and global context. Also one systematic technology based approach is proposed for managing SWM system.

KEYWORDS: Solid waste management, urbanization, Information technology, RFID.

***Corresponding author**

Rubul Kumar Bania

Assistant Professor

Dept. Computer Application,

North-Eastern Hill University, Tura Campus,

Meghalaya (India).

Email id. rubul.bania@gmail.com

INTRODUCTION

Change is good but the present directions of man made changes are unmaintained and biased towards the whole ecological systems. The rapid growth of urbanization and economic development has not only changed the physical shape and size of the cities but are also exerting significant additional pressure on the infrastructural services across the Indian cities and globally [1]. As per the Indian Census of 2011, our nation is contributing 11 percent of the world population and having 53 metropolitan cities which may jump to 87 in 2031 [2]. In global context, each year the urban populations generate around 1.3 billion tons of waste. That's expected to soar to four billion tons by 2100 and study reveals that only two per cent of waste or the garbage is currently recycled or composted[1]. The rest ends up in landfills, where it may pose a potential risk to wildlife and the environment. Here, the term **'***Wastes***'** means those materials which are discarded after use at the end of their intended life-span. Due to the cause of demographic changes and urbanization, it becomes difficult for the habitants of the society as well as for the municipal bodies to manage the wastages. It's very omnipresent to thrown waste is in the form of rotting piles in open spaces or maybe in roads.

Solid waste (SW) [3,4] is one types of waste which are unwanted or useless solid materials generated from human activities in residential, industrial or commercial areas. The contents of SW are organic material, glass, metal, plastic paper etc. Change in the physical and chemical composition of Indian SW with time is shown in Table 1[5]. Also there is a potentiality of hazards components such as toxic, non-toxic, flammable, radioactive, infectious etc. As Planning Commission Report[5] the total SW generated in urban India has been estimated at 62 million tons per year (TPY) (0.573 million metric tons per day (MMT/d) and it is projected that by 2031 these urban centers will generate 165 million tons of waste annually and by 2050 it could reach 436 million ton.

Table 1: Change in sources of municipal solid waste.

Year	Bio-degradable	Paper	Plastics	Metal	Glass	Rags	Inert	Others
1996	42.21	3.63	0.60	0.49	0.60	-	45.13	-
2005	47.43	8.13	9.22	0.50	1.01	4.49	25.16	4.02
2011	42.51	9.63	10.11	0.63	0.96	-	17.00	-

In the literature, depending on the materials and sources, solid waste is classified into various groups:

i. *Municipal Solid Waste* (MSW) [9,14,23]: It consists of household waste, construction and demolition debris (CnD), sanitation residue, and waste from streets, generated mainly from residential and commercial complexes. Sometimes it may include commercial and residential waste generated in municipal or notified areas in either solid or semi-solid form.

ii. *Industrial Solid Waste* (ISW) [6]: The types of wastes which are generated by different industrial activities during manufacturing of products. It includes dirt and gravel, masonry and concrete, scrap metal, oil, solvents, chemicals, scrap lumber, even vegetable matter from restaurants also. In a majority of the cases these types of waste are termed as hazardous waste as they may contain toxic substances, are corrosive, highly inflammable, or react when exposed to certain things e.g. gases. Different studies have revealed the untreated and partially treated wastewater from industries, factories are commonly fed back into a near lying body of water and it directly affects the water bodies and marine eco-systems.

iii. *Biomedical waste or hospital waste* [18]: It is usually infectious waste that may include waste like sharps, disposables, anatomical waste, cultures, discarded medicines, chemical wastes, etc., usually in the form of disposable syringes, swabs, bandages, body fluids, human excreta, etc. These types of wastes are more serious threat to human health, therefore proper management is required.

iv. *Electronic waste* (E-waste) [8]: It is a kind of waste of electronic products that have become unwanted, non-working or obsolete, and have essentially reached the end of their useful life. Because technology advances at such a high rate, many electronic devices become "trash" after a few short years of use. E-waste is created from different electronic items categorized as: computers, TVs, monitors, cell phones, PDAs, VCRs, CD players, fax machines, printers, etc.

Solid Waste Management (SWM) [9,11] is one form of management system which reduces or eliminates the adverse impact on the environment & human health generated by different types waste. Each municipality tries to give to its habitants the SWM facility. In United state of Americas, few decades earlier itself watertight garbage cans were first introduced and sturdier vehicles were used to collect and transport wastes. Slowly the changes occurred through the global context and in today's scenario a number of different processes are involved in effectively managing waste from the municipal areas. These include monitoring, collection, transport, processing and recovery, disposal/treatment. Among all these mentioned steps of waste management, solid waste collection (SWC) [9,15] process, deals with different challenging issues . In this process normally vehicles starts with different human resources from their sources (say from office complexes or from collection centers) and they travel in fixed routes to collect waste by visiting locations of some municipal areas. During this time of waste collections from diverse areas or regions, vehicles usually keep their engines running, even during the loading-unloading of waste bins, which results in huge consumption of fuel and greater emissions. Every month a large amount of the total budget allotted for SWM by state or central government are used for SWC process and these budgets goes to fuel

consumption only[14]. On the same line there is a substantial hazardous effect on the environment due to the consequent pollution emissions by those vehicles. At the same time, the overall SWM system is still manual in many of the countries including our nation; hence there is no exact information about waste generation and collection which led to an unplanned management. As a result site selection for trash bins, collection point, disposal point or recycling station is accomplished without proper planning. In addition, waste collections are conducted without perceiving or analyzing demand and the drivers are normally responsible to construct travelling routes for waste collection. Therefore, various researches [3,6,7,12] have showed that diverse advance technologies including information technology have helped to handle different types of SWM related issues with a more efficient manner in terms of cost, time, risk and environment. In this work mainly the focus is given on the overall Municipal solid waste management system with the help of recent advance technologies, as this wastes is coming under the umbrella of SW, so formally the overall management techniques for handling these wastes are considered.

MOTIVATIONS AND OBJECTIVES

Use of advance computer based technologies with latest information and electronic communication medium might provide an innovative way to address the different issues related to SWM system. Also at the same time every municipality aims to attain more sustainable cities with proper waste collection and disposal system. By considering these motivational facts this study is carried out.

The main objectives of this work are as follows:

i. To address the solid waste management problem and to represent the usefulness of recent advance computational based technologies.
ii. To present a structured and comprehensive investigation on existing methods in global and in Indian context.
iii. To proposed a schematic structure for solid waste management system.

PROBLEM STATEMENT

In waste management system, N numbers of sources are available in different municipalities under a city. Each source point generates some waste material in each day. The waste management system collects these waste form the different sources and process it through different plants[7,22]. Therefore, total waste management cost SWM_{Cost} for N number of sources is:

$$Total\,SWM_{Cost} = \sum_{i=1}^{N} C\_cost + \sum_{i=1}^{N} T\_cost + \sum_{i=1}^{N} P\_cost + \sum_{i=1}^{N} R\_cost + \sum_{i=1}^{L} D_{cost} + E \qquad (1)$$

Where C_cost = collection cost, T_cost = transportation cost, P_cost = processing cost, R_cost = recycling cost, D_{cost}= disposal cost for L number of unused or produced waste material after processing and E is some amount of extra cost that are depending on other parameter such as accident, maintenance of collection centre, transfer station and vehicle. The profit gain from different N number of waste generation sources is revenue

$$SWM_{Profit} = \sum_{i=1}^{N} P_{Income} - SWM_{Cost} \qquad (2)$$

Where P_{Income} is achieved from the sales of recyclable materials, sales of compost product and the sales of electronic or some other goods. A waste management system always tries to develop a mechanism that maximizes the profit SWM_{Profit} by minimizing the cost generated by waste collection cost and waste processing cost.

So, the above two equations are applicable for the generalized SWM system and also it is applicable for Municipal SWM systems too.

ROLE OF ADVANCED RECENT COMPUTATIONAL TECHNOLOGIES

Municipal SW in India typically contains 51% organic waste, 17% recyclables, 11% hazardous and 21% inert waste. Survey carried out by National Engineering and Environmental Research Institute, Nagpur (NEERI) has reported that Indian waste consists of Nitrogen content (0.64 ± 0.8) %, Phosphorus (0.67 ± 0.15)%, Potassium (0.68 ± 0.15)%, and C/N ration (26 ± 5) % . However, about 40% of all MSW are not collected at all and hence lies littered in the city/town and finds its way to nearby drains and water bodies, causing choking as well as pollution of surface water. Unsegregated waste collection and poor collection systems cause the dumping of wastages in the open area, which generates leachate[10] and toxic gas emissions. Leachate contaminates the groundwater as well as surface water in the vicinity and gaseous emissions contribute to global warming [15]. In many of the cities of our country waste bins are neither properly designed nor properly located and maintained. Bins are common for both decomposable and non-decomposable waste (no segregation of waste is performed) and the waste is disposed at a communal disposal center.

The overall target of a MSWM system is to monitor, collect, waste sorting and dispose solid wastes generated by the population groups, in a cost effectively manner without hampering the environment. To meet the different goals a sophisticated decision-making system is required in any type of MSWM, for which the information technologies are becoming more important to handle the

large-scale of geographical data, different routes, monetary accounts and overall analysis. Also, payment and waste collection methods in many of the countries and states are still manual, and are thus subject to possible errors and mistakes common in manual operation. The drivers or some other workers have to handle all the tasks in collection make the process more risky. Environmental informatics[17,18], which is a new interdisciplinary field between environmental science and information technology, was formally developed in 1980s to orchestrate various informatics tools and facilitate decision-makers to intimately link the domain knowledge with envisioned social, economic, ecological, and environmental objectives. But, systems that are not using computational mechanism may pose various limitations in terms of site selection, collection monitoring, intelligent recycling, inefficient waste disposal etc. Technologies can help to overcome these challenges to make a sound MSWM system.

The application spectrum of the latest technologies mainly includes regional planning, vehicle routing and scheduling, sorting and site rehabilitation [20,22]. Regional planning is a typical problem that aims to control the waste flows at a regional level to plan the optimal number of treatment and disposal plants, determine the combination of different shipping strategies, and determine a new site's location according to engineering conditions. The technology based MSWM systems that are widely used can be categorized into three groups followed by data communication technologies[9].

i. *Spatial technologies based systems* which are designed by using geographical information system (GIS) and/or global position system (GPS) or remote sensing (RS) as main technology [11,13]. SWM operators adopt this system to monitor the location of trash bins and collection vehicles during collection. However, municipalities are facing problem with solid waste route optimization for collection that has various effects on collection efficiency, cost and pollutant emissions. There are many researches on optimization problems such as vehicle routing problem (VRP), capacitated vehicle routing problem and vehicle routing problem with time windows to reduce cost, less emission, serve customers and depot through optimized route. ArcGIS [19] is very commonly used software for solid waste collection optimization. Using this software, the real-time road conditions (traffic, blockage, etc.) can be optimized, and a route can be designed accordingly.

ii. *Identification technologies based systems* where barcode or radio frequency identification (RFID) [7, 14, 20] tags are installed with waste bins for tracking identification to determine their location and to acquire the time of collection. A typical RFID system consists of tags and readers, application software, computing hardware, and middleware. Rapid development of RFID technology and its implications on the field of environment have pay more attention to the usage of RFID for more efficient collection of trash and recyclable materials.

iii. *Data acquisition technologies based systems* that contain several sensory elements installed inside trash bins such as image sensor, distance sensor, volumetric sensor etc. to observer its status [9].

iv. *Data communication technologies* that are normally used in all previous three kinds of system to facilitate the transmission of captured or analyzed data [15, 16, 18]. An Internet of things (IOT) [18] which is a network that may allow the MSWM administrators to track wastes through the collection and transportation chain and routing the suitable way.

Similarly, in another study[18] researchers have noted that environmental informatics tackles specific environmental problems related to the applications of information technology and systems engineering techniques. With regard to building, maintaining, and developing knowledge-based or artificial intelligence (AI) systems, the spectrum of environmental informatics for SWM can be classified into five categories[18]: database system (DBS), geographical information system (GIS), decision support system (DSS), expert system (ES), and integrated environmental information system (IEIS). All these categories are highly demanding and useful for a reasonable SWM system.

STATE-OF-THE-ART REVIEW

The Municipal SWM systems are studied in the literature in many ways. In this section a brief review on the state-of-the-art computer based technologies used in global and Indian context to automate the monitoring, collection and transportation of different wastes from different sources are highlighted.

One of the useful technologies in a few recent years is the utilization of spatial technologies in environmental modeling, as spatial analysis is very important for many environmental studies and engineering. These technologies are effective to handle complex spatial information and to provide platforms for the integration of various models, interfaces and sub-systems as well. Zsigraiova *et al.*, [13] have proposed a novel dynamic scheduling and routing framework by incorporating GIS which reduces the transportation and operation costs (fuel, labor, maintenance) in MSW collection specially glass waste collection in Barreiro of Portugal. Also they performed a sensitivity analysis of the vehicle loading process to isolate the influence of the dynamic load on fuel consumption and pollutant emissions in cullet collection. Faccio *et al.*, [16] have developed a framework about the traceability technology available in the optimization of SWC process with an advanced vehicle routing model integrated with the real time traceability data. They have applied their framework in an Italian city of near about one lakhs inhabitants. Waste Bins are installed with programmable microprocessor sensing technologies and all vehicles are installed with GPS receiver, RFID receiver, weighing system, GPRS module and a mobile laptop with vehicle traceability software application.

Data from waste bins and vehicles locations are collected by the control server parses from GPRS/GPS network. The main strength of their overall proposed system is the well-defined framework for enabling traceability and monitoring of the overall waste disposal processes through dynamic scheduling and routing models. In another study [19] authors have targeted for finding the best routes of solid waste collection network in Nablus city of Palestine. This study seeks the optimal route that minimizes the total travelled distance by the different waste collection vehicles for which operational cost reduced. The overall problem is considered as vehicle routing problem (VRP) and it is optimized by using popular genetic algorithm. The propagation of identification technologies, such as barcode and RFID technologies brought a new strength to this MSWM system. The RFID system automates the process and reduces the driver's responsibility. Waste management efficiency is thus improved by applying RFID. In [24], researchers have proposed a waste bin and truck monitoring system in Malaysia that enabled with RFID and data communication systems. An integrated system was proposed which focused on RFID technology with GPS, GIS and camera for designing an intelligent monitoring system for bins and trucks. Also this model incorporate database which stores bin and truck information related with the bin and truck identity. Arebey *et al.*,[20], have developed a bin level detection model based on gray level co-occurrence (GLCM) matrix feature extraction approach and tested in Bangi city of Malaysia. This work presents a set of GLCM displacement and quantization parameters along with the number of textural features which are tuned to determine the best parameter values of the bin images. Image classification and grading is based on training and testing of multi layer perceptron (MLP) and K-nearest neighbor (K-NN) classifiers. This proposed model can be used in bin level classification and grading thus providing a solution for bin detection, monitoring and management. In another very recent study[14] Waste collection process is studied as a route optimization problem by including a large amount of expenditure in terms of capital, labor, and variable operational costs. This research study has proposed a modified particle swarm optimization (PSO) algorithm in a capacitated vehicle-routing problem (CVRP) model to determine the best waste collection and route optimization solutions. In this study, threshold waste level (TWL) and scheduling concepts are applied in the PSO-based CVRP model under different datasets. Paulraj *et al* [15] have proposed a very dynamic mobile manipulator based system for municipal solid waste sorting for recycling process. The reported system is capable of automatically recognizing three types of recyclable materials mainly aluminum can, plastic bottle and tetrapack from thermographic images. Different features are extracted and feed them into clustering model to map into bag-of-word vectors to build the SVM classifier model. Experimental results shows better classification accuracy with varying scale, rotation, and illumination conditions in a cluttered environment.

In our country also in some of the states and districts some researchers have attempted to incorporate computer based technologies in MSWM systems. Das *et.al.*,[22] have proposed an optimal MSW collection and transportation scheme that focuses on the problem of minimizing the length of each waste collection and transportation route to the processing plant site or to waste landfill area. Authors have studied the problem of waste collection in Kolkata city, where the different sources of wastes are scattered by heterogeneous way and utilizes the technologies like GIS and GPS. Bhambulkar *et. al.*,[23] have used the ArcGIS Network Analyst tool for best routing identification applied in municipal waste collection in Maharashtra, Nagpur city. In order to collect MSW that couldn't be collected by the standard waste collection vehicles, due to size and other prohibitive obstacles (road blockage, accidents) have also been taken into consideration for solving MSWM problem.

Besides the computational based approaches for MSWM for collection, transportation etc., in Indian context following waste to energy technologies [26] are identified for post processing of MSW, they are as follows [5]:

i. Biomethanation for wet biodegradable wastes.
ii. Conventional microbial vermi composting for wet biodegradable wastes.
iii. Preparation of briquette/ pellets/ fluff as Refuse Derived Fuel (RDF) from dry high-calorific value combustible wastes.
iv. Incineration / Gasification for dry high-calorific value combustible wastes.

PROPOSED SCHEME FOR MUNICIPAL SOLID WASTE MANAGEMENT SYSTEM

The proposed structure or scheme for managing the solid waste is diagrammatically shown in Figure 1. The proposed scheme is a hybridization of general MSW system with the advance computational based technologies. Normally in different sources of waste generators like households, offices, market, organizations, proper manual monitoring is required to identify the types waste and from these sources a collection of segregated solid wastes are collected by some of the nearest collection centers. Now in this proposed scheme the RFID tag will be affixed to two different waste containers (solid waste (biodegradable) and solid waste (non-biodegradable) of various sources, and the RFID readers can be installed on waste collection vehicles. To identify the types of waste in waste containers, different image processing, machine learning techniques based small devices and sensors can installed according to the applicability. The collection vehicles are also outfitted with a scale to measure the mass and weight of the waste bins, and the household or other sources will be recognized in the course of the RFID tag which is attached on the waste bins. The

RFID reader which is installed on the vehicles will read the tags of the waste bins when it is placed on the truck's scale and then it will record the exact time and place of collections and send this data, via intermediate servers, to the main disposal system so that respective disposal processing method can be prepared. In the respective server side all the various data are stored and it will calculate and it will send the vehicles for optimal vehicle route direction with traffic information, so that less amount of fuel consumption will takes place. The sensors or the devices will send the information to the servers when the waste bins of some localities have crossed a limit in the bins to so the municipal vehicles can come and pick up the stuffs.

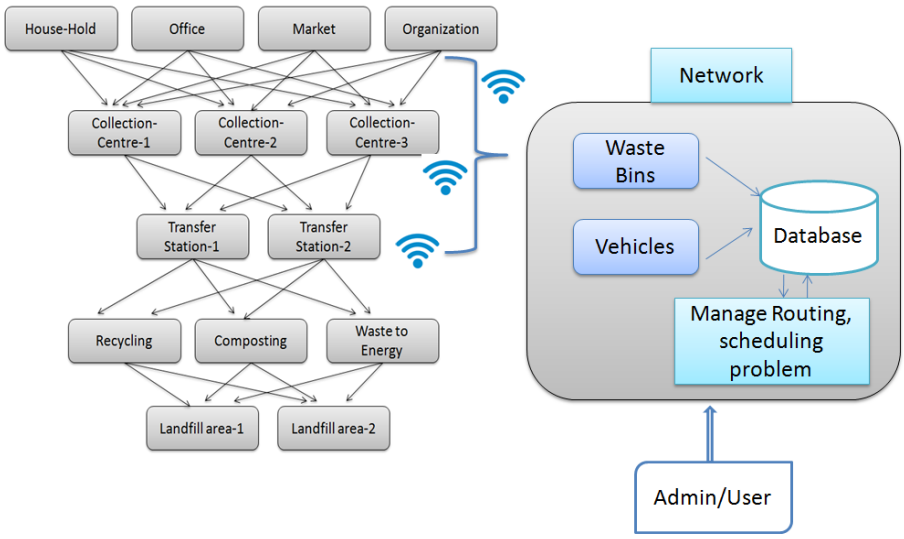

Figure 1: Proposed block diagram for solid waste management system

All these details data from all device readers, including waste bins, types, weight, collection time and vehicles are collected regularly (preferably daily) and process through each other based on a wireless mesh network (WMN) with proper secure databases. Then administrator(s) and the administrative users can do regular monitoring and control of the waste-disposal process. Also the task of the administrator will be to look after the customer information, area information and different utilization of device information. After processing and collecting the waste with proper optimization system, accumulated solid wastes are then transferred to some of the adjoining transfer station. From those transfers station also all the information will be transferred to the server for proper management. The sorting of the solid waste is again a difficult task, therefore by applying innovative artificial intelligence and image processing task sorting of the waste can be done so that different segregations of waste get generated. Finally the segregated waste are transferred to nearby categorized waste processing plant for different processes like recycling, composting, waste to energy course of action. After doing these processes it is necessary to transfer the unutilized waste from processing plant to the nearest landfill site.

DISCUSSION

Utilization of technologies with respect to environment is multifaceted and complex paradigm. It can output both positive and negative results for the environment. Now, in our country one of the important declarations in the development agenda of NDA government is that of Open Defecation Free India by 2019. The "Swachh Bharat Mission" (SBM) is a major initiative of the Ministry of Urban Development (MoUD), Government of India. It is launched on the occasion of the birth anniversary of Mahatma Gandhi on 2nd October, 2014. In developed countries like USA, Malaysia, Japan etc., automated waste management systems are developed for proper maintenance of manpower and money. It will be beneficial if our government agencies also incorporate in larger scale the recent technologies to manage the huge quantity of generated waste. It may be difficult to apply the mentioned computational based technologies in every cities and town of our country due to poor and unplanned development of the roads but it is not impossible though. Also it is highly demanding to conduct awareness programs by stack-holders and by different NGO's in those areas which are not under the umbrella of district municipalities and which are also under municipal areas by addressing different challenges. So that daily basis household wastes generated by the urban areas and village areas get disposed properly. Public needs the basic understanding not to throw all the organics and recyclables waste in open areas to emit methane gas, contaminating water sources, and creating costly waste management with auditing fees. Government should have to plan properly to set up potential waste to energy projects in metro Politian cities to generate more revenues from the solid wastes.

CONCLUSION

Municipal solid waste management is a multidisciplinary activity which includes generation, source separation, storage, collection, transfer and transportation, processing and disposal. In this article in a nutshell an introduction to SWM and the utilization of recent advance technologies are highlighted. A comprehensive study on the existing methods and techniques used in global and in our nation context is carried out. Also one systematic idea is proposed for managing MSWM system by utilizing the proper advance technologies. Though an appropriate and careful government policy may extract the maximum benefits from modern technologies for the improvement of clean and green society but more or less it is our individual concern to make our environment clean. As all of us are responsible for generating waste, therefore rather than blaming the government to unable to handle this critical issue, if we make little bit changes in our mindset than at least some fruitful results may outcome. Every individual should realize the importance of source segregation at generation

point as biodegradables, inert and recyclable material for the proper utilization of the waste management systems.

REFERENCES

1. Hoornweg, D., and Bhada-Tata, P., What a Waste- A Global Review of Solid Waste Management. Urban development series, Washington, 2012; 15.
2. Census., Registrar general of India. 2014; Available from URL: http://censusindia.gov.in/
3. Shekdar, A.V., Sustainable solid waste management: An integrated approach for Asian countries. Waste Management. 2009; 29(4): 1438-1448.
4. Naveen, B. P., Malik, R. K., and Kontoni , D. N., Municipal solid waste management in India - challenges and feasible solutions, In the Proceedings of 8th International Conference from Scientific Computing to Computational Engineering, Athens, 2018.
5. Planning Commission Report, Reports of the task force on waste to energy (vol-I) 2014, Available from URL: http://planningcommission.nic.in/reports/genrep/rep_wte1205.pdf.
6. Sharholy, M., Ahmad , K., Mahmood , G., and Trivedi , R.C., Municipal solid waste management in Indian cities-A review. Waste Management. 2008; 28: 459-467.
7. Wu, Y.B., Tao, Y., Pan , X.H., and Wu, P.C., RFID-based optimization method for inventory control strategy. Applied Mechanics and Materials. 2010; 34: 1149-1153.
8. Gupta, S., E-waste Management: Teaching how to Reduce, Reuse and Recycle For Sustainable Development- Need of Some Educational strategies, Journal of education and practice. 2012; 2(3): 74-86.
9. Hannan, M.A., Mamun, Md. A., Hussain, A., Basri, A. and Begum, R.A., A review on technologies and their usage in solid waste monitoring and management systems: Issues and challenges. Waste Management. 2015; 43(2): 509-523.
10. Kalamdhad, A.S., Kazmi , A.A., A study on influence of waste composition in rotary drum, Proc. International Conference on Waste Engineering and Management. Hong Kong, 2008.
11. Kanchanabhan, T., Mohaideen, J.A., and Srinivasan, S. Optimum municipal solid waste collection using geographical information system (GIS) and vehicle tracking for Pallavapuram municipality. Waste Management research. 2011; 29(3): 323-339.
12. Narkhede, S.d., Attarde , S.B., and Ingle, S.T., Combined Aerobic Composting of Municipal Solid Waste and Sewage Sludge. Global Journal of Environmental Research. 2010; 4(2): 109-112.

13. Zsigraiova, Z., Semiao,V., and Beijoco, F., Operation costs and pollutant emissions reduction by definition of new collection scheduling and optimization of MSW collection routes using GIS. Waste Management. 2013; 33(4): 793-806.
14. Hannnan, M.A., Akhtar, M., Begum, R.A., and Basri, H., and Scavino, E., Capacitated vehicle-routing problem model for scheduled solid waste collection and route optimization using PSO algorithm. Waste Management. 2017; 71: 31-40.
15. Paulraj , S. G., Hait, S., and Tahkur, A., Automated municipal solid waste sorting for recycling using a mobile manipulator, In the Proceedings of International Design Engineering Technical Conferences and Computers and Information in Engineering Conference. North Carolina, 2016.
16. Faccio, M., Persona, A., and Zanin, G., Waste collection multi objective model with real time traceability data. Waste Management. 2011; 31(12): 2391-2405.
17. Hua, L., Shao, G., Zhao, J., A concise review of ecological risk assessment for urban ecosystem application associated with rapid urbanization processes, International Journal of Sustainable Development. 2017; 24(3): 248-261.
18. Lu, W. J., Chang , N. B., and Liao, L., Environmental informatics for solid and hazardous waste management: advances, challenges, and perspectives. Crit. Rev. Environ. Sci. Technology, 2013; 43(15) : 1557-1656.
19. Assaf, R., and Saleh, Y., Vehicle-routing optimization for municipal solid waste collection using genetic algorithm: the case of southern nablus city. Civil and environmental engineering reports. 2017; 26(3): 43-57.
20. Arebey, M., Hannan, M.A., Basri, H., Begum, R., and Abdullah, H., Solid waste monitoring system integration based on RFID, GPS and camera. In the Proceedings of International Conference on Intelligent and Advanced Systems, Philippines, 2010; 1-5.
21. Desai, S. N., Shah, M., Zaveri, P., Route Optimisation for Solid Waste Management using ArcGIS Network Analyst: A Review, International Journal of Engineering Technology Science and Research. 2018; 5(1): 137-142.
22. Das, S., and Bhattacharyya, B. K., Optimization of municipal solid waste collection and transportation routes. Waste Management. 2015; 43(1): 1-11.
23. Bhambulkar, A. V., Municipal solid waste collection routes optimized with ArcGis network analyst, International journal of advanced engineering sciences and technologies. 2011; 11(1): 202-207.

24. Hannan, M.A., Arebey, M., Begum, R.A., and Basri, H., Radio frequency identification (RFID) and communication technologies for solid waste bin and truck monitoring system. Waste Management. 2011; 31(12): 2406-2413.
25. Nleya, M. L., Chisadza ,Z., and Manyuchi, M., Integrated Municipal Solid Waste Management System, In Proceedings of International Conference on Biological, Chemical and Agricultural Sciences, Mauritius 2016.
26. Luthra, A., Waste-to-Energy and Recycling, Economic & Political Weekly. 2017; 52(13): 51-58.