"Effective Management of Solid waste by using GIS and Artificial Intelligence Based Support System"

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ABSTRACT

A rapid rise in inhabitants across the globe has led to the inadmissible management of waste in various countries, giving rise to various health issues and environmental pollution. Municipal solid waste deposition in metropolitan areas has become a major concern that, if not addressed, can lead to environmental degradation and possibly endanger human health. It is important to adopt a smart waste management system in place to cope with a range of waste materials. There has to be appropriate planning for proper waste management by means of analysis of the waste situation of the area. This project would deal with, how Geographical Information System can be used as a decision support tool for planning waste management. A model is designed for the case study area in an Indian city for the purpose of planning waste management. The suggestions for amendments in the system through GIS based model would reduce the waste management workload to some extent and exhibit remedies for some of the SWM problems in the case study area. The waste management issues are considered to solve some of the present situation problems like proper allocation and relocation of waste bins, check for unsuitability and proximity convenience due to waste bin to the users, proposal of recyclable waste bins for the required areas and future suggestions. The model will be implemented in the Thane city area, a satellite town of Mumbai city as case study area data for the analysis and the results will suggest some modification in the existing system. In doing so, an efficient solution for smart and effective waste management using machine learning (ML) and the Internet of Things (IoT) is proposed in this paper which is expected to reduce the waste management workload to a certain extent.

Keywords: MSW, Solid waste management(SWM),Recyclable waste, Smart waste bin, Machine Learning, Artificial Intelligence, GIS, Internet Of Things(IoT)

1.0 INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Now a days, many cities and towns are growing rapidly in India. Among the fast growing towns and cities, Mumbai is probably the prominent one. This is due to its strategic position located along the ancient long distance trade routes. The city is expanding rapidly with increasing number of industries and service sectors such as hotels, restaurants, small and micro enterprises. We have chosen the satellite city of "Thane" as our case study area. The city of Thane governed by Thane Municipal Corporation (TMC), is a metropolitan city in Maharashtra, India. It is situated in the north-eastern portion of the Salsette Island. The City of Thane is located on the north-western side of the state of Maharashtra, the city is an immediate neighbour of the City of Mumbai and a part of the Mumbai Metropolitan Region. TMC is spread over 128 $km2$. The city has 9 administrative wards and 33 electoral wards. TMC, currently has an estimated population of 25,98,590 with around 5,19,718 number of residential properties.

As per the approved Solid Waste Management - Detailed Project Report of TMC, the population of Thane is expected to increase by 2.8 times by 2051.

Thane is currently generating 1,039 tons of municipal solid waste on daily basis. Out of this total waste, 624 tons is wet waste while 390 tons is dry waste including inert waste. Around 15 tons per day is the generation of domestic hazardous waste, while 10 tons per day comprises of sanitary waste. Thus, keeping into consideration, the current waste generated and increase in population, the Thane Municipal Corporation foresees Waste to Fuel/ Value added products/ Energy plant to efficiently channel waste management.

As town grows, so does the amount of waste production specially the solid hazard waste. It is inevitable that waste production and management problems increases with rapid urban growth resulting in pressure on sanitary related problems in the city. Because of Improper waste management practices and limited public and community trucks and containers, people are being forced to dispose their wastes in any open fields. Poor sanitary situation has become a common characteristics of many villages in the city. This necessitates the applications of Geo-information systems on landfill site suitability assessment as a solution to address the problem and effectively manage the wastes in the city. The present situation of direct dumping of the waste without proper inspection and separation leaves a serious impact of environmental pollution causing a tremendous growth in health related problems. "Domestic, industrial and other wastes, whether they are of low or medium level wastes, they are causing environmental pollution and have become perennial problems for mankind." (Ramasamy SM, et. al., 2003). If this situation is not handled in a proper manner within time then it would lead to worse consequences on a global level. There has been awareness regarding waste management amongst many countries. There has been development of new technologies for improving the waste management systems. GIS is one of the new technologies which have contributed a lot in very less time span to the waste management society. "The Geographic Information System (GIS) helps to manipulate data in the computer to simulate alternatives and to take the most effective decisions."(L. Narayan., 1999)

The most effective solution to overcome the problem of environmental pollution is the use of the Internet of Things- (IoT-) and machine learning- (ML-) based waste management system . (A. Khoa, C. H. P. Tran, P. Duc Lam et al.), These technologies can provide real-time information about the waste and provide an optimized path for the waste collection trucks, reducing the cost and time for the overall process.

1.2 SOLID WASTE

Solid waste is the unwanted or useless solid materials generated from human activities in residential, industrial or commercial areas.

It may be categorised in three ways.

According to its:

- origin (domestic, industrial, commercial, construction or institutional)
- contents (organic material, glass, metal, plastic paper etc)
- hazard potential (toxic, non-toxin, flammable, radioactive, infectious etc).

It is a bit complex to summarise the total meaning of the term solid waste in a single definition. In a wider term waste can be said as, the items which are no more in use and are not expected to be used in future either. The only solution to these items is to destroy them. There are also some technical descriptions to the term solid waste which are; "Solid waste is the term used to describe non-liquid waste materials arising from domestic, trade, commercial, agricultural, industrial activities and from public services." (S. Palnitkar., 2002).

"The 'Municipal Solid Waste' includes commercial and residential wastes generated in municipal or notified areas in either solid or semi-solid form excluding industrial hazardous wastes but including treated bio-medical wastes." (MoEF., 2000). Though the definition of the term will remain same in all times but it changes its features in different times. There is a large variation in solid waste from country to country. The type of solid waste depends on the commodity usage and lifestyle of the people.

1.2.1 Classification of solid waste based on constituents sources and characteristics

1. Source-based classification:

- Residential: This refers to wastes from dwellings, apartments, etc., and consists of leftover food, vegetable peels, plastic, clothes, ashes, etc.
- Commercial: This refers to wastes consisting of leftover food, glasses, metals, ashes, etc., generated from stores, restaurants, markets, hotels, motels, auto-repair shops, medical facilities, etc.
- Institutional: This mainly consists of paper, plastic, glasses, etc., generated from educational, administrative and public buildings such as schools, colleges, offices, prisons, etc.
- Municipal: This includes dust, leafy matter, building debris, treatment plant residual sludge, etc., generated from various municipal activities like construction and demolition, street cleaning, landscaping, etc.
- Industrial: This mainly consists of process wastes, ashes, demolition and construction wastes, hazardous wastes, etc., due to industrial activities.
- Agricultural: This mainly consists of spoiled food grains and vegetables, agricultural remains, litter, etc., generated from fields, orchards, vineyards, farms, etc.
- Open areas: this includes wastes from areas such as Streets, alleys, parks, vacant lots, playgrounds, beaches, highways, recreational areas, etc.

2. Type-based classification:

Classification of wastes based on types, i.e., physical, chemical, and biological characteristics of wastes.

- Garbage: This refers to animal and vegetable wastes resulting from the handling, sale, storage, preparation, cooking and serving of food.Garbage comprising these wastes contains putrescible (rotting) organic matter, which produces an obnoxious odour and attracts rats and other vermin. It, therefore, requires special attention in storage, handling and disposal.
- Ashes and residues: These are substances remaining from the burning of wood, coal, charcoal, coke and other combustible materials for cooking and heating in houses, institutions and small industrial establishments. When produced in large quantities, as in power-generation plants and factories, these are classified as industrial wastes. Ashes consist of fine powdery residue, cinders and clinker often mixed with small pieces of metal and glass. Since ashes and residues are almost entirely inorganic, they are valuable in landfills.
- Combustible and non-combustible wastes: These consist of wastes generated from households, institutions, commercial activities, etc., excluding food wastes and other highly put risible material. Typically, while combustible material consists of paper, cardboard, textile, rubber, garden trimmings, etc., non-combustible material consists of such items as glass, crockery, tin and aluminium cans, ferrous and non-ferrous material and dirt.
- Bulky wastes: These include large household appliances such as refrigerators, washing machines, furniture, crates, vehicle parts, tyres, wood, trees and branches. Since these household wastes cannot be accommodated in normal storage containers, they require a special collection mechanism.
- Street wastes: These refer to wastes that are collected from streets, walkways, alleys, parks and vacant plots, and include paper, cardboard, plastics, dirt, leaves and other vegetable matter. Littering in public places is indeed a widespread and acute problem in many countries including India, and a solid waste management system must address this menace appropriately.
- Biodegradable and non-biodegradable wastes: Biodegradable wastes mainly refer to substances consisting of organic matter such as leftover food, vegetable and fruit peels, paper, textile, wood, etc., generated from various household and industrial activities. Because of the action of micro-organisms, these wastes are degraded from complex to simpler compounds. Non biodegradable wastes consist of inorganic and recyclable materials such as plastic, glass, cans, metals, etc.
- Dead animals: With regard to municipal wastes, dead animals are those that die naturally or are accidentally killed on the road. Note that this category does not include carcasses and animal parts from slaughter-houses, which are regarded as industrial wastes. Dead animals are divided into two groups – large and small. Among the large animals are horses, cows, goats, sheep, pigs, etc., and among the small ones are dogs, cats, rabbits, rats, etc. The reason for this differentiation is that large animals require special equipment for lifting and handling when they are removed. If not collected promptly, dead animals pose a threat to public health since they attract flies and other vermin as they decay. Their presence in public places is particularly offensive from the aesthetic point of view as well.
- Abandoned vehicles: This category includes automobiles, trucks and trailers that are abandoned on streets and other public places. However, abandoned vehicles have significant scrap value for their metal, and their value to collectors is highly variable.
- Construction and demolition wastes: These are wastes generated as a result of construction, refurbishment, repair and demolition of houses, commercial buildings and other structures. They consist mainly of earth, stones, concrete, bricks, lumber, roofing and plumbing materials, heating systems and electrical wires and parts of the general municipal waste stream.
- Farm wastes: These wastes result from diverse agricultural activities such as planting, harvesting, production of milk, rearing of animals for slaughter and the operation of feedlots. In many areas, the disposal of animal waste has become a critical problem, especially from feedlots, poultry farms and dairies.
- Hazardous wastes: Hazardous wastes are those defined as wastes of industrial, institutional or consumer origin that are potentially dangerous either immediately or over a period of time to human beings and the environment. This is due to their physical, chemical and biological or radioactive characteristics like ignitability, corrosivity, reactivity and toxicity. Note that in some cases, the active agents may be liquid or gaseous hazardous wastes. These are, nevertheless, classified as solid wastes as they are confined in solid containers. Typical examples of hazardous wastes are empty containers of solvents, paints and pesticides, which are frequently mixed with municipal wastes and become part of the urban waste stream. Certain hazardous wastes may cause explosions in incinerators and fires at landfill sites. Others such as pathological wastes from hospitals and radioactive wastes also require special handling. Effective management practices should ensure that hazardous wastes are stored, collected, transported and disposed of separately, preferably after suitable treatment to render them harmless.
- Sewage wastes: The solid by-products of sewage treatment are classified as sewage wastes. They are mostly organic and derived from the treatment of organic sludge separated from both raw and treated sewages. The inorganic fraction of raw sewage such as grit and eggshells is separated at the preliminary stage of treatment, as it may entrain putrescible organic matter with pathogens and must be buried without delay. The bulk of treated, dewatered sludge is useful as a soil conditioner but is invariably uneconomical. Solid sludge, therefore, enters the stream of municipal wastes, unless special arrangements are made for its disposal.

1.3 SOLID WASTE MANAGEMENT

Solid waste is composed of garbage or refuse, a broad array of materials discarded by households, businesses, industries, and agriculture. Solid waste can be discarded as food waste, paper, plastic, glass, rubber, wood, textile, metals, stones, rocks, and ceramics. The major sources of the solid waste are residential, institutional and commercial waste and City Corporation or municipal services (street sweeping) wastes. Municipal Solid Waste (MSW) disposal has been enormous concern in developing countries due to poverty, population growth, urbanization and ineffectual fund (UNDP, 2004). MSW management is a big challenge due to number of problems including; inadequate management, lack of technology and human resources, shortage of collection and transport vehicles, and insufficient funding. Waste disposing is another important part of waste management system, which requires much attention to avoid environmental pollution. The most common problems associated with improper dumping includes; diseases transmission, fire hazards, odor nuisance, atmospheric and water pollution, aesthetic nuisance and economic losses. The effectiveness of solid waste disposal depends upon the selection of proper site and current global trend of waste management problems stems from unsustainable methods of waste disposal, which is ultimately a result of inadequate planning.Waste management processes comprise complex operations and non-linear parameters due to the multiple interconnected processes involved and the highly variable demographic and socio economic factors affecting the overall systems. The emerging artificial intelligence (AI) techniques are sought to be well-suited for application in the SWM field .The AI technology deals with the design of computer systems and programs that are capable of mimicking human traits such as problem solving, learning, perception, understanding, reasoning, and awareness of surroundings.

1.3.1 Key components of solid waste management

Solid waste management can be divided into five key components:

1. Generation-Generation of solid waste is the stage at which materials become valueless to the owner and since they have no use for them and require them no longer, they wish to get rid of them. Items which may be valueless to one individual may not necessarily be valueless to another. For example, waste items such as tins and cans may be highly sought after by young children.

2. Storage-Storage is a system for keeping materials after they have been discarded and prior to collection and final disposal. Where on-site disposal systems are implemented, such as where people discard items directly into family pits, storage may not be necessary. In emergency situations, especially in the early stages, it is likely that the affected population will discard domestic waste in poorly defined heaps close to dwelling areas. If this is the case, improved disposal or storage facilities should be provided fairly quickly and these should be located where people are able to use them easily. Improved storage facilities include:

• Small containers: household containers, plastic bins, etc.
• Large containers: communal bins, oil drums, etc.
• Shallow pits
• Communal depots: walled or fenced-in areas

In determining the size, quantity and distribution of storage facilities the number of users, type of waste and maximum walking distance must be considered. The frequency of emptying must also be determined, and it should be ensured that all facilities are reasonably safe from theft or vandalism.

3. Collection-Collection simply refers to how waste is collected for transportation to the final disposal site. Any collection system should be carefully planned to ensure that storage facilities do not become overloaded. Collection intervals and volumes of collected waste must be estimated carefully.

4. Transportation-This is the stage when solid waste is transported to the final disposal site. There are various modes of transport which may be adopted and the chosen method depends upon local availability and the volume of waste to be transported.

Types of transportation can be divided into three categories:

• Human-powered:	**open hand-cart, hand-cart with bins, wheelbarrow, tricycle**
• Animal-powered:	donkey-drawn cart
• Motorised:	tractor and trailer, standard truck, tipper-truck

5. Disposal-The final stage of solid waste management is safe disposal where associated risks are minimised. There are four main methods for the disposal of solid waste:

• Land application: burial or landfilling
• Composting
• Burning or incineration
• Recycling (resource recovery)

1.4 Geographical Information System (GIS)

GIS is a computer system for capturing, storing, checking, integrating, manipulating, analyzing and displaying data related to positions on the Earth's surface. Typically, a Geographical Information System is used for handling maps of one kind or another. These might be represented as several different layers where each layer holds data about a particular kind of feature. Each feature is linked to a position on the graphical image on a map and a record in an attribute table. GIS allows us to view, understand, question, interpret, and visualize data in many ways that reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts. A GIS helps you answer questions and solve problems by looking at your data in a way that is quickly understood and easily shared. GIS technology can be integrated into any enterprise information system framework.

1.5 CONTRIBUTION OF GIS IN SWM

There are several phases in solid waste management, right from the stage where it is generated till it reaches its final destination or at a stage where it is no more a threat to the environment. It is observed that solid waste management can be bifurcated into mainly two phases. One is the waste management in the area where it is generated and second is the management of waste at dumping grounds. This paper will cover the first phase which deals with the municipal waste management within the city limits. This includes the issues related to the waste generation, their storage, collection and removal from the collection points. The waste is generated in all areas but there is large variation in its type and quantity. According to (R. K. Garg., 2002), the quantity and nature of the waste generated vary with the activities and with the level of technological development in a country. "The issue of waste is not only because of the increasing quantities but also largely because of an inadequate management system." (E. Tinmaz& I. Demir., 2005). The suggestions made after considering these variations would maintain a balance in this variation by considering the areas which generate more or a different category of waste. GIS could help in dealing with several factors simultaneously which needs to be considered while planning waste management. "GIS is a system of computer hardware and software, designed to allow users to collect, manage, analyse and retrieve large volume of spatially referenced data and associated attribute data collected from a variety of sources."(S. Upasna & M. S. Natwat., 2003). There are several problems which need to be treated with decisions taken considering all the related factors.. "The spatial operation is normally performed in conjunction with GIS functionality found in most GIS software." (G. J. Lunkapis., 2004). GIS is a good decision support tool for planning waste management. There was a research conducted for Landfill site selection in Malaysia and it was mentioned in the report (G. J. Lunkapis., 2004) that, the purpose of the research was to use Geographic Information System (GIS) as a tool to aid the decision-making process and to test its effectiveness using some established government guidelines. "By assessing the location of something and then combining it with what's around it, you're able to make a decision you were never able to make before," said Erich Seamon, GIS manager for San Francisco. (Wired News Publication website) . Solid waste management comprises several phases, starting from the stage where the waste is generated till it reaches its final destination or at a stage where it is no more a threat to the environment. It is observed that solid waste management can be bifurcated into mainly two phases. The development of Geographic Information System (GIS) and its use throughout the world has contributed a lot in improving waste management systems. GIS helps to manipulate data in the computer to simulate alternatives and to take the most effective decisions. However there are still some drawbacks and deficiencies in applying the method extensively. Since routing models make extensive use of spatial data, GIS can provide effective handling, displaying and manipulation of such geographical and spatial information. For example, proposed a model for the system of Municipal Solid Waste (MSW) collection that provides planning for distribution of collection bins, load balancing of vehicles and generation of optimal routing based on GIS.

1.6 Contribution of Machine Learning Algorithms in Solid waste Management : IoT (Internet Of Things) with machine learning(ML) algorithm can be used in waste management system to develop the smart city in effective manner. Waste can be classified depending on its characteristics by using ML classifier algorithm. ML is a multidisciplinary field that covers computer science, probability theory, statistics, approximate theory, and complex algorithms, and its theories and methods have been widely used to solve complex problems in engineering applications (Sanchez-Lengeling and Aspuru-Guzik, 2018; Zhang et al., 2020). ML uses data to "train" and learns how to complete tasks from the data through various algorithms. ML algorithms include artificial neural networks (ANNs), support vector machine (SVM), naive Bayes, K-nearest neighbor (KNN), decision tree (DT), random forest (RF), and adaptive network fuzzy inference system (ANFIS). As the most important branch of ML, deep learning (DL) has developed rapidly in recent years and has gradually become a research hotspot in ML. The workflow of the traditional ML methods usually consists of three steps: (1) data processing and feature extraction, (2) choosing the proper ML algorithms and parameters, and (3) testing and evaluating performance. Applications of Machine learning algorithms send the monitored data through an android application, and these kinds of android application are well suited for deep learning approach, and they collect the real time data with the help of Bluetooth technologies.

1.6.1 Intelligent Garbage Bins : The role of Artificial Intelligence AI in waste management begins with intelligent garbage bins. In our smart waste container recycling and management system, we have used smart bins in which waste-detecting sensors are fixed. These sensors are capable of sending signals to the nearest sensor referenced to the base station.

Smart bins are an intelligent waste management system. They have wireless ultrasonic fill-level sensors embedded inside which detect how full the bin is and then, through the IoT, this data is sent to a cloud-based monitoring and analytics platform. On the basis of this data, waste collection services can optimise their routes and frequency. Smart bins also use a solar-powered trash compactor which activates at a pre-set level, enabling them to hold a great deal more waste (up to 8 times) and avoid overflowing. This allows municipalities to optimize waste collection routes, times, and frequencies. In

Figure below, it can be easily noticed that the pickup truck is directed to those waste bins which are more than 90% full or about to be 100% full and not selecting the path which is partially filled. In this case, the pickup truck selects the most optimized route that not only reduces its costs in the collection round trips but also shields from the unfavourable conditions.

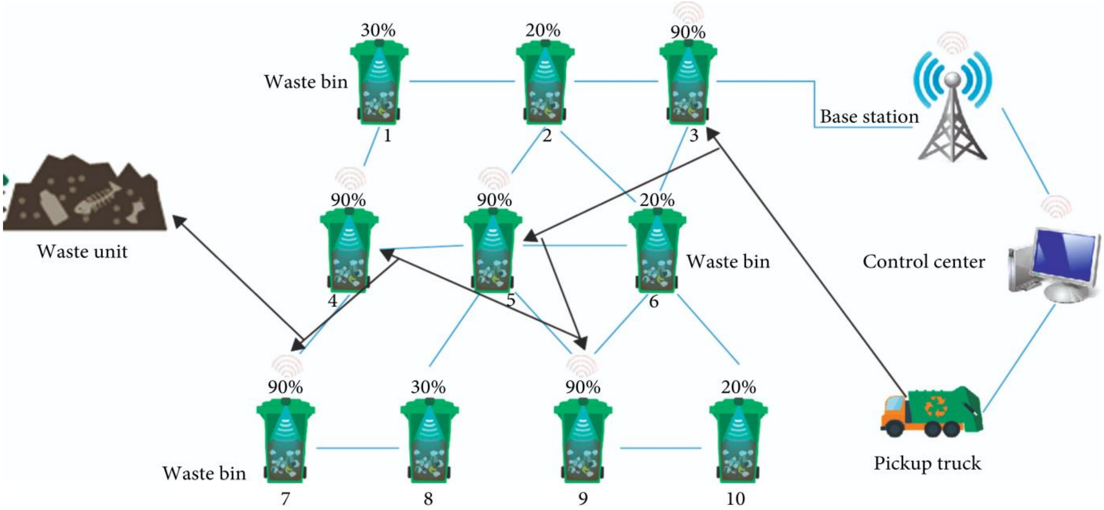


Fig.1.1 Function of smart bin network.

1.6.2 Smart waste Management:

The waste management system predominantly corroborates the disposal and treatment of different types of waste. Thus, it safeguards human beings, animals, and surroundings. Adequate waste management techniques can save much money, which will lead to improved air quality and less environmental pollution. Simultaneously, the advanced regions are discovering and implementing some efficient techniques for efficient waste management and coming up with enormous constructive results It will be impossible to manage such a huge amount of waste in the upcoming five years by the current situation. Thus, it is better to take all the necessary actions required for the effective management of waste. Therefore, we must adopt the best techniques and practices to treat waste efficiently to have healthy environment As per the reports, the waste generated per person per day varies from 0.17 to 4.67 kilograms. The overall waste is anticipated to exceed about 45 billion tons by 2055, which will be over double growth for the identical period. Income and generation of waste are directly proportional to each other. Waste is a huge income source, so its treatment and disposal must be done in the best possible way. It is estimated that, by 2050, per day waste generation of the low-income and middle-income nations would rise to 45%, and for the high-income countries, it can increase to 20% .

The most effective solution to overcome the problem of environmental pollution is the use of the Internet of Things- (IoT-) and machine learning- (ML-) based waste management system . These technologies can provide real-time information about the waste and provide an optimized path for the waste collection trucks, reducing the cost and time for the overall process. The issues faced by current waste management systems are improper scheduling; that is, the waste collectors do not know that they had to pick the waste. They also do not know precisely about the drop-off location . One significant application is that IoT innovation has become an effective apparatus to manufacture brilliant urban communities.

A couple of arrangements have presented IoT gadgets to appraise inboxes' fill levels and send this information over the web for better decisions. Waste management hierarchy is shown in Figure below :

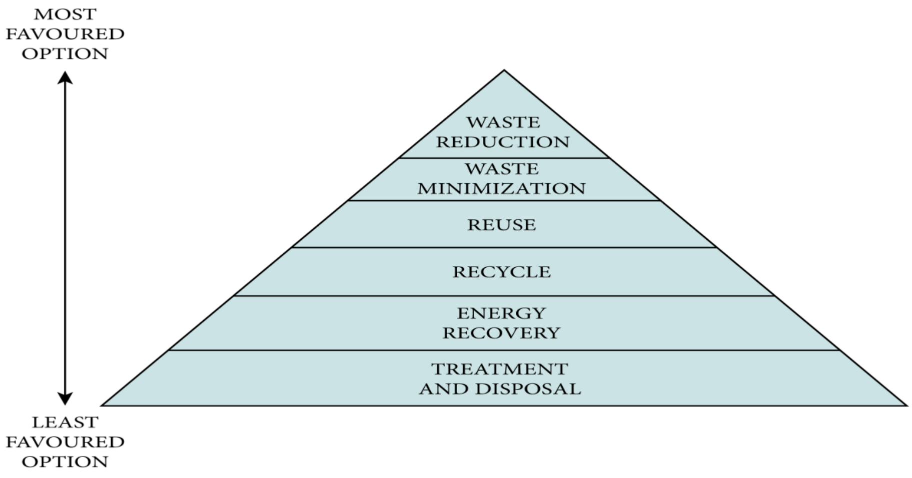


Fig .1.2 Smart waste management hierarchy

Smart waste management includes the following list of activities:

(i) Controlling and monitoring the collection of wastes; efficient and speedy transportation to the recycling units/point
(ii) Preventing the waste from spilling from the waste bins during transportation to the recycling units
(iii) Speedy transportation to recycling units so that the traffic condition will not be bothered in peak hours
(iv) Proper storage and maintenance in the storage unit

1.6.3 Waste Recycling : Recycling has become increasingly important as overloaded cities grow around the globe. As waste generation increases and resources become scarcer, recycling becomes more important. Recycling is one of the world's most critical and complex environmental problems. It is necessary to create a system that can remove or at least minimize this problem. With its ability to reduce greenhouse gas emissions, such as CO2, CH4, N2O, and CFCs, recycling helps protect the environment by lowering air and water pollution and reducing energy consumption. Technology for smart cities should take solid waste collection seriously since it is important for the environment and influences society. There is a risk of disease spreading due to the overflowing of waste bins. A fast increase in the number of people squanders provides rise to inefficient waste management. The weight sensor has been inserted into one of the waste bins and it may be used to find out how much dust has been collected. System software can be designed so that while the waste bin is full, the remaining height from the barrier height can be displayed on the screen. Ultrasonic sensors can alert a GSM modem when the garbage reaches the limit level. The modem can keep sending alerts to a designated expert of the garbage already retrieved from the bin. Trash vehicles may collect waste using robot components when the local expert sends a message to the separate administrator.

1.6.4 Sorting of Waste by Internet Of Things(IoT) and Machine Learning :

Artificial intelligence has revolutionized industries. But while most people have heard of self-driving cars and facial recognition software, many of us are unaware of the enormous impact AI has had for the waste management and recycling sectors. In a waste management facility. AI and robotics are constantly improving the processes we rely on to collect, transport, sort, and process all types of waste, from **medical waste** to **biohazard waste**. waste needs to be sorted at a waste management facility. When it comes to the role of artificial intelligence in automated sorting, one statistic tells us all that we need to know: human workers sort between 30 and 40 recyclables per minute while AI-powered machines can handle up to 160. Moreover, machines can work around the clock. The role of AI in smart sorting is similar to the role of AI in manufacturing—items on a conveyor belt, whether that includes waste or new products, are scanned with cameras and analyzed by deep learning algorithms. Robotic arms and other apparatuses then pull the items off the belt for further processing which, in the case of waste management, includes sorting. Sorting plastic and recycling waste is a major bottleneck for most waste management facilities. The vast majority of recycling processes begin with a single-sort system, meaning all recycling materials end up in the same box. When this box reaches a facility, items like plastic and cardboard must then be separated. When it comes to sorting, the role of **AI in recycling** becomes incredibly intricate. That's because AI-powered sensors are a vast improvement compared to traditional optic sensors. They can detect items made from different materials as well as nuances between items of the same material, including whether an item has been chemically contaminated, ensuring purity of the waste stream.

1.7 PROBLEMS STATEMENT

Waste management issues are coming to the forefront of the global environmental agenda at an increasing frequency, as population and consumption growth result in increasing quantities of waste. Moreover, technological development often results in consumer products of complex composition, including hazardous compounds, which pose extra challenges to the waste management systems and environmental protection at the end of their useful life, which may often be fairly short (e.g. cell-phones and electronic gadgets).Mumbai is among the fast growing towns in India. It is expanding rapidly with increasing number of industries and service sectors such as hotels, restaurants, small and micro enterprises. Thus as town grows, so does the amount of waste production specially the solid hazard waste. It is inevitable that waste production increases with rapid urban growth, which in turn results in pressure on sanitary related problems in the town. ''In Thane, Mumbai, most waste generated and disposed in the waste disposal site are organic wastes and this shows that wastes are not considered as resources in the city. Open air burning of wastes, inland fills, and incineration plants that lack effective treatment for gas emission can cause air pollution. Improper waste management practice and limited public and community toilets, etc forced the people to dispose their wastes in any open fields ''.

1.8 PROBLEMS DUE TO MISMANAGED WASTE

There are several problems which arise due to the present waste situation. The route causes of these problems can be analysed by studying the situation. The problems are discussed and used to form the frame of guidance for the proposed model. There is only one type of bin in the city which is meant to collect all categories of waste. Due to this there is direct disposal of waste to the dumping grounds without segregation. The accumulation of waste around the bins is the basic problem faced wherever there is a uncovered bin and there is no proper base platform for bins. Also there is a lack of waste handling awareness amongst the citizens. Due to all these reasons there is an unpleasant situation around the bin. This accumulated and uncovered garbage becomes an invitation for several problems in the locality. Bad odour is created around the waste bins area which makes unpleasant environment. This also affects the economic factor, market value of the area decreases if there is a badly maintained waste area nearby as it poses a bad aesthetics. The accumulated waste becomes a breeding ground for insects, flies, different bacteria, and micro-organisms this could create health problems. "The decaying matter provides suitable material for harmful insects (mosquitoes and flies) to thrive and rapidly causing diseases." (M. K. Virk, et. al., 2004). Stray animals like cats, dogs, goats and cows come to the bins in search of food end up in spreading the garbage around the bins. "Unprotected waste is the carrier of many kinds of diseases like cholera, diarrhoea, dysentery and tetanus. The epidemic of plague in Surat in September 1997 was mainly due to the growth of rodents at waste disposal sites." (M. K. Virk, et. al., 2004). Often it has been observed that the cows swallow polythene bags along with the vegetables, plant foliage and other food materials. This causes serious health problems to them. Hardev Singh, director of the Veterinary Department of Uttar Pradesh state says in an interview to the India Today magazine, "Cows consume garbage wrapped in polythene bags. This is how polythene is causing the death of thousands of cows every year." This is not only a health problem to animal but also to humans. "The Animal Husbandry Department of Uttar Pradesh has come up with an alarming discovery: Milk from cows which have polythene bags clogging their stomachs can cause diseases like tuberculosis and cancer."(India Today). From these examples we can asses the seriousness of the problem and the urgent need to solve it. The situation becomes worse in the rainy season. As the waste bins are open from both top and bottom the waste is directly exposed to the rain. The water makes the waste wet and it even drains out of the bin from the bottom, thus polluting the streets.

1.9 Drawbacks in the existing waste management system

There are several systematic approaches in the system but there are some short comings which we will be discussed. "India has lagged behind in terms of adopting technologies for solid waste management. In particular, collection, treatment and disposal of waste require urgent consideration."(Shaleen S & Suneel P., 2001). From the observations made in the existing system we will draw some conclusions which would help us to frame the guidelines for proposing the new model for waste management in Thane, Mumbai.

- There is often an allocation of waste bin at a location when there is a public demand, this location selection from the public would be based on their convenience. But the place chosen may not be fulfilling some technical factors and planning aspects.
- Multiple and manual handling of the waste.
- No separate bins for recyclable waste.

Very less data on records.

2.0 LITERATURE REVIEW :

2.1 RESEARCH ARTICLE 1

Logistic Management and Spatial Planning for Solid Waste Management Systems using Geographical Information System. This as an overview and a discussion of the paper, "Logistic Management and Spatial Planning for Solid Waste Management Systems using Geographical Information System" written by Arbindo Ogra and was published in Map Asia 2003. At the end of the discussion there are critical views on this paper work.

2.1.1 City waste management background

This system is designed for the conditions of Dehradun city in Indian. It is based on the practical observations regarding the functions and the time wise needs of the city. The city conditions are such that the inhabitants face a lot of problems due to improper management of solid wastes. This is not because the municipality is not doing their work properly or due to work negligence, but it is due to the old conventional working methods which need to be upgraded with the advanced system like GIS and a better management system. "Municipal bodies are unable to prove a 100% efficient system and even are not able to reach the efficiency of 60%." (Ogra, A., 2003). The maintenance and the management of data is an important thing which was found missing in the system due to which it was quite difficult to know about the systems functioning. The data should be managed in an integrated way to reduce the complexity of different issues related to the function of the work involved in the waste management system.

2.1.2 Problems

The commonly observed problems in the area or the key issues were;

- The garbage is not lifted at regular intervals.
- The waste bins are most of the time in a pitiful condition lying full of garbage without being cleaned and also bins are either uncovered or not lying upright.
- There was no segregation of solid waste categories like paper, glass, polythene, food material etc.
- On the other side the municipal authorities had their reasons for this mismanaged of the waste maintenance.

- The citizens do not throw the waste inside the bins so it often lies outside and around the bins, making the area around the bin look dirty.
- The waste lifting capacity is quite less in comparison with the amount of waste generated in the city.
- There is also a shortage of manpower, equipments and machinery.

2.1.3 Other problems due to poor SWM

Now the situation was such that there were several drawbacks of this garbage accumulation and even worse were its consequences, some of them are,

- The biggest threat to a locality is, the waste could be a breeding ground for flies, insects, bacteria, fungus and many such micro-organisms. This could spread diseases and it would become worse during rainy season and the contamination might end up in some epidemic like cholera, malaria etc.
- Bad odour is created around the garbage area, making an unbearable environment.
- Poor waste pickers pose a serious threat to public health.
- Animals like cats, dogs, goats and cows come to the garbage in search of food and end up in spreading the garbage around the bins.
- The economic factor is also affected, the market value of a particular area decreases if there is a badly maintained waste area near by as it poses a bad aesthetics.
- It overall leaves a bad impression and poses a threat to the environment

2.1.4 GIS approach

The city conditions are such that the inhabitants face a lot of problems due to improper management of solid wastes. This is not because the municipality is not doing their work properly or work negligence but it is due to the old conventional working methods. “Municipal bodies are unable to prove a 100% efficient system and even are not able to reach the efficiency of 60%.”(Ogra.A., 2003). There are several areas where the municipal bodies are striving hard to provide best of their services for the betterment of the city. They even follow their methods promptly and perform their duties in a way that could run this system perfectly. In these kind of situations, there has to be a better and a refined system which is developed with the consideration of all the facts and figures of the situation. This can be achieved with the help of GIS which can handle different data forms like spatial as well attribute data simultaneously. The system seems to fell short in terms of its approaches to maintain a clean environment and it needs to be upgraded and refined. Solid Waste Management is one of the important areas where the problem arises from time to time. “One of the simplest way to bring innovations in any system is to document and study the existing system and bring the possible reforms by adopting appropriate measures at various levels through the introduction of innovative and cost effective solutions.” (Ogra.A., 2003).

The type of dataset which is required is the information about the areas where most waste is generated, the data related to the employees involved in the waste management programme. A systematic map with sufficient information related to the waste generated in different areas and even along the roads and junctions. The working strategies which are been propose for Municipalities for the situation of the Dehradun city were as follows;

To provide a waste management service which can be acceptable on existing financial constrains. This action plan proposed two elements of the plan first the creation of an efficient Management Information System (MIS) & Geographical Information System (GIS) and the second the provision of planning and management such that there are possibilities of improvement in financial and institutional support. Due to the financial constrains it was suggested to incorporate those options which can promote the improvement in the system without a major capital investment. So it was proposed to create the MIS and GIS information. It was found that the data related to SWM is not available on one platform for utilising it for proper decisions regarding the planning and management. In the existing situation the system lacks supervision of workers and a proper logistic management and spatial planning. According to (Ogra. A., 2003) through continuous planning and dynamic management these systems can be designed to have capacity meet demand on a continuous basis. The process of planning can not be stopped and suggested as an ideal for the system as the city situations of waste generation and the service requirements change in due course of time, so the planning also have to be upgraded and reconsidered. GIS can make the analysis of the situation and a future trend can be predicted which will help in planning for a long term. This system propose the collection of data from different sources and formation of the map layers like, ward and city map, demographic map showing the area wise population distribution, waste generation map of different areas, existing waste collection pattern from the bins, employment distribution in different wards, information about the other organisations involved in the SWM and existing route plan of waste lifting. From these layers the analysis can be done to derive the logistics and spatial planning. “The more the layers in terms of information, the more will be better decision analysis.” (Ogra.A., 2003). There are some suggestions in this spatial planning proposal which are supposed to be considered while working in GIS, they are as follows;

- Identification of exact location of waste bins, either with GPS or surveys and demarcating on the base map.
- Maintaining a record of the waste bins
- A map showing the quantity of waste generated in different areas.
- A map showing the distances between the bins.
- A record of the employees like, sanitary inspectors, sweepers etc should be maintained. This would help to study and workout the ratio of employees for the assignment of facilities and equipments for the assigned work.
- Identification of existing waste lifting pattern
- Presence of different private organisations, groups and associations which contribute to the waste management programme.
- Location of the waste dumping ground/landfill site.
- Record of the available vehicles and equipments for the waste management.
- Identification of the areas for the display of hoardings for the bins. This would be an added benefit in terms of a good revenue generating means.
- Allocating a unique number to all the waste bins so it can be easily and quickly located in case of any complaint registered or planning and maintenance.
- Maintaining a record about the amount of waste being dumped at the landfill site.
- Record of the responsibilities and assignment of work ,equipments, vehicles etc.of the waste maintenance crew and also the logistics information about the transportation involved in the system.
- Assigning the responsibilities to the crew members by making groups and allotting them the specific areas of work. This would help in proper distribution of work.

2.1.5 Planning and management

In planning management it is discussed that the municipal body is responsible for the waste management in the city and therefore there should be a phase wise planning for the implementations of the action plans. As apart of the logistics management and spatial planning for waste management it is important to develop the adoptability of the system for the GIS based proposal. The first phase includes the training workshops for the employees of the municipal departments and other concerned users. This training would help them to get acquainted to the new concepts and technologies of GIS. The second phase is anticipated to have training on the database management and collection of different information for the attribute data. The third phase consists of selection of software and implementation of GIS in the area. This new implemented system is supposed to take up the major city waste management issues. In the future proposed works it is suggested to deal with the post implementation issues which may further evolve new systems. In the conclusion it has been discussed about the reformation in the concepts of the data management and the analysis carried with the help of GIS. Ones the waste management department is aware of the total functionality of the GIS system, it will get acquainted with its functionality. Then there will be an entire record of all the things related to the waste management and suitable logistic management and spatial planning can be achieved. This can be done with the help of GIS analysis on the different layers for practical implementations.

2.1.6 Critical views

In Dehradun city waste situation it was discussed about the waste bin conditions with waste lying outside and around the bins. In this situation, apart from the inconvenience caused to the citizens it also makes it very inconvenient for the waste collectors to do their work properly. They have to collect that waste manually and it interrupts in their work. There has been a proposal to maintain a inventory of the employees involved in the waste management programme so that data related to the employees involved in the waste management programme. This can help to analyse if the employees are sufficient in numbers to handle the situations or the work distribution can be done in shifts to make the work going with the limited number of employees. It was discussed about the use of GIS layers which can be worked upon using software like Arc GIS, Arc Map etc. to get the required information or a new layer from them. By applying the functions like overlaying, applying buffer for proximity analysis or by applying queries through a structured query language the required information can be extracted.

- Demographic map can be used to know the more waste generating areas.
- The category of waste like domestic, industrial, commercial etc can be found out easily with the help of the land use map.
- Existing location of the waste bins and the street maps will provide the proximity of the bins to the waste collection service routes. In case of any inconveniency for the waste collecting crew the bins can be re located.
- A map showing the current waste generated and the waste generated in different wards, sectors and along the roads, streets and junctions.

There has been enlisted some points which are said to be an important exercise to begin with. The points overall covers many waste management issues, but they are very generalise and require a lot of data and proper analysis using the GIS software. There will be a requirement to develop several models to apply all those points on the real time data. This project mainly emphasis on the management information system.

2.2 RESEARCH ARTICLE 2

A GIS based transportation model for solid waste disposal-A case study on Asansol municipality. This as an overview and a discussion of the paper, "A GIS based transportation model for solid waste disposal-A case study on Asansol municipality." written by M. K. Ghosh, A.K. Dikshit& S.K. Sharma, published in Science Direct, September 2005. At the end of the discussion there are critical views on this paper work.

2.2.1 Framework for waste collection system

In this paper it has been tried to propose an effective solid waste management system for municipal waste, excluding the waste categories like industrial, constructional and hospital waste. The following points were been considered in the framework of the proposed work of waste management plan;

- Appropriate method of on-site storage.
- Appropriate method of bulk storage of waste.
- Appropriate method of primary collection of waste.
- Appropriate method of transportation of waste using Geographical Information System (GIS).
- Appropriate method of waste disposal.
- Financial expenditure on whole solid waste management plan. (M. K. Ghosh, et. al., 2005).

The city Asansol is situated in Barddhahaman district in the state of West Bengal, India. It is an industrial area and is spread on an area of 127.24 square kilometres. The waste management comes under the Asansol Municipal Corporation (AMC) which has 50 wards. The total number of households is 95,293 and there is an average occupancy of 5 per house. There are two major points covered in this paper. They are, planning of bins and optimising the vehicular route for the waste collection vehicle. Satellite data is used for the generation and updating of spatial database like road network, waste bin location, landfill site and waste collection vehicle garage. The whole work is divided into phases.

2.2.2 Waste storage

There were three types of waste bins proposed according to their waste carrying capacity and they were allotted to different areas as per the quantity of waste generated in that area. A positive point about this pattern of bin allocation is that some extra capacity is being provided and the bin utilisation factor is assumed to be 50%. This is a good consideration for the increase in waste generation in future. The roads in the city have been classified into three categories as per their width i.e. major, minor and others. Waste bins are placed beside all the three types of roads and a collection pattern is decided.

2.2.3 Waste collection

There are three types of waste bins proposed and three types of vehicles for collecting the waste from them. All the vehicles are having a mechanised system for waste collection. Though it is a costly affair for an initial investment but it reduces the pick-up time and would cover a larger area in comparatively less time in comparison with a manual waste collection vehicle. The waste collection vehicles are divided into three categories and it will collect waste from location of the waste bin placed in areas which occur on different road categories like A-type of vehicle will be collecting waste from the A-type of waste bins which are placed only on or in proximity of major roads. In the same way there is a categorisation of the B-type vehicle as a front loading mechanised which lifts B-type bins and can travel on both major and minor roads. The C-type vehicle is a small three tire auto-rickshaw and it collects waste from the C-type bins. It can be used on all road networks especially the congested areas where other vehicles cannot reach.

2.2.4Waste collection methodology

In the methodology one landfill and a garage is taken in consideration for the study purpose. Each vehicle is operated with two crew members who are totally responsible for the waste collection from the bins and bringing it to the disposal site. There is a general speed limit assumption for a type of a vehicle. A and B the type of waste collection vehicles start from the garage and starts collecting the waste bins from the respective locations of the bins and carry the filled bins to the dumping site, evacuate them and carrying them to their respective locations. This way they go on replacing the filled bins with empty bins and at the end of the day will go back to the garage. The schedule for the C-type bin is a bit different. It collects the waste from C-type bins and disposes the waste at the nearest A-type bin. It repeats this process with other bins and returns to the garage at the end of the day.

2.2.5 Route Optimisation GIS model for transport of waste

Though there is a general speed limit assumption for a type of a vehicle, but there is an option for the input user defined speed limit for different types of vehicles in the GIS router model. There can be input options through link or arc impedances of the proposed GIS model for delays due to, road congestions, traffic jams, one-way and others (M. K. Ghosh, et. al., 2005). As the A-type of vehicle uses only the major road network, the roads and the A-type of bins are selected from the map data. On the basis of the proximity of the bins the order for collection of the bins is calculated. In this way the optimal path for the vehicle is generated, further edition can be done to the initial planning. This allows making the clusters of the bins which are in proximity. Each cluster is allocated to a vehicle for bin collection. The clusters are formed in such a way that the time of the total working hours is sufficient to cover the allotted cluster. The planning for the B-type of vehicles and bins is also done in the similar way. The clustering of 50 bins is formed as it is calculated that at the maximum, these number of bins can be conveniently cleared at a time. With the help of optimal path the total time required is calculated and displayed. The user can select any cluster he wishes to work with. Different options of optimum paths can be found and each vehicle is allotted the cluster of bins to collect waste. A final optimal path between the clusters is generated as soon as the choice of cluster is entered. In case of C-type of collection vehicles the routing is dependent on the A- type of vehicles as the waste collected by them is to be dumped in A-type of bins. So the collection timings of the A type bins are taken into consideration and according to its schedule the optimal path of C- type cluster is made. The total number of vehicles required to clear the C- type bins is calculated from the total working hours of the vehicle. Three GISroute modules have been developed using Arc Marco Language for the route network analysis.

2.2.6 Results and conclusion

The results included the different routes for the three categories of waste collection vehicles. Details about the waste collection vehicles travel time, distance and number of bins cleared in a day were given. The estimate of the waste management plan and operating cost of the Asansol municipal corporation was also calculated. These statistics were given to have the total budget idea of the proposed new waste management system. A GIS based optimal routing model was used for the Asansol city waste management. Different parameters like, population density, waste generation capacity, road network, waste storage bins and waste collection vehicles were considered to develop the model. It was intended to plan cost efficient waste collection route for transportation of waste to the landfills. It can be a good decision support tool for waste transport, fuel consumption, work distribution amongst the vehicles for load balance and generation work schedules for both employees and vehicles.

2.2.7 Critical views

The area where GIS have been used very nicely in this system is, the coordination in the allocation of different collection vehicles, their constrain over the bin type and the type of road network it can use. There is a good detailing in the data of the Asansol city as there is the information about the area covered number of wards, number of houses and an average occupancy per house. This information and the total amount of waste generated from the whole city can give statistics on the ratio of waste generation per house or even per person. Waste bins were proposed according to the capacity and they were allotted to different areas as per the quantity of waste generated in that area. But only this would not solve the waste problem, segregation is also an important issue to be considered. It is good to have road width information as used in this paper. It makes it convenient while planning for different capacities of waste bins which require different types of vehicles for waste collection from the bins. There are often some areas which generate a large quantity of waste and require a bigger waste bin, but do not have a major road access for a collection vehicle which lifts a big sized bin. This can be considered a result of inadequate city planning concern. Any how some alternative has to be worked in this situation by either providing small side bins or by increasing the road width. The mechanised waste collection vehicle is a costly affair for an initial investment, but it reduces the pick-up time and would cover a larger area in comparatively less time as compared with a manual waste collection system. It has other positive aspects like it will reduce the labour involved in waste collection. There is a lot of waste spread in manual handling of waste which is reduced in the mechanised vehicle. In this waste collection system, the area remains without a waste bin till the collection vehicle carries the bin to dumping site to evacuate it and brings the empty bin to its location. If it is done in a shorter duration then it is considerable but if it gets delayed by any reason to bring back the empty bin then it would be inconvenient for the public. There should be a standby option, but it is again not easy to workout. The functionality of the C-type collection vehicle is a bit questionable as it is not in favour of avoiding the multiple handling of the waste. The results achieved in this analysis are in detail and it is quite helpful to compare it within the system or with some other analysis method and model used. One of the factors which makes this system questionable is that, all employees need to have good knowledge of operating the system in order to extract the necessary information about the route details. This is appreciable for a situation where the vehicle operator has to take a decision for selection of a collection route, but he at the same time has to be expert enough to operate the system on his own or there has to be some one to find it for him. It is necessary to provide the basic training to the concern employees to get acquainted with the functioning of this system.

2.3 RESEARCH ARTICLE 3

Estimation and allocation of solid waste to bin through geographical information systems. This as an overview and a discussion of the paper, “Estimation and allocation of solid waste to bin through geographical information systems,” presented by, R. Vijay, A

Gupta, A. S. Kalamdhad, S. Devotta, published ISWA, 2005. At the end of the discussion there are critical views on this paper work.

2.3.1 Introduction

This paper presents a GIS based waste management facility provision. It includes the estimation of waste generation, location of waste bins, type, size and frequency of waste removal from the bins. All this is computed with the help of GIS using the information data from different sources. The waste generation data is calculated in this model on the basis of two factors, the local population density and income groups. These two factors were used in GIS with other data like road elevation survey data to generate the triangulated irregular network (TIN). This TIN was generated by the GIS, helped in properly allotting and allocating the waste bins throughout the study area. Different parameters were considered in the allocation like the distance between the bins and its proximity from the households. The slope of the road factor was also considered for the convenience of the handcart pullers. The national guidelines specified in "Manual on Municipal Solid Waste management", CPHEEO 2000 were followed. A study area of 4 square km was considered. This study was carried to estimate the quantity of waste generated in the waste bins and the allocation of related services with the help of GIS. The data used for this analysis was collected from mainly two departments, the City Municipal Corporation (MC) and Public Works Department (PWD). The data collected from MC was the boundary area of solid waste collection, demographic data i.e. population density and income group distribution. The data collected from PWD was the data of the road network of the study area, information about the different road classes and the elevation survey data of the road network. The information about different types of waste bins available in the market and their waste carrying capacities was collected from the waste bin manufacturers. There were some considerations made while working the design of the model. As the waste was of mixed category, there was no consideration of separate bins for organic and non organic waste. But it was specified that the separate waste collection can be considered in case of separate bins by modifying the algorithms with minor changes for separate waste fraction estimation.

2.3.2 Methodology

The methodology was carried in two phases. The first phase comprised of preparation of the GIS database from the available information from different sources. The second phase comprised of computation of waste generation estimation and bin allocation.

2.3.3 First phase

It consists of preparation of thematic maps which includes the digitisation of spatial data i.e. digitisation of the base map of the study area. Representing the demographic data on the maps which included display of the polygon features having population density information in their attribute data. This is represented in person / sq. meter. Then the representation of different income groups on the map. This was done by drawing polygons representing the different income groups like, lower, medium and higher income groups (LIG, MIG, HIG) on the basis of the quantity of waste generated i.e. kg /capita/day by these groups. Then the preparation of the road network map was carried. This included all the roads and streets which were possibly used in the waste management services. The road level attribute was also added in the corners of the road links and this was as per the survey map of the study area.

2.3.4 Second phase

In this phase the GIS based programs were used to compute the waste generation and allocation of waste bins. It was carried by overlaying different information layers like, waste bins, TIN of waste generation. Waste estimation and allocation, determination of type and size of bins was also carried. Preparation of suitable waste bins coverage locations. This coverage network of bins should follow the (CPHEEO 2000) national guidelines according to which, a waste bin network should have a inter bin spacing of not more than 500 m and the maximum distance of a waste bin for household should not be more than 250 m. Creation of the triangulated irregular network for waste different calculations. The areas like water bodies, barren land and other non waste generating areas were removed from the areas under consideration. Then the superimposition of different data's like population density, income group, road network and the location of bins on the network (TIN) was carried out to extract the estimation of solid waste generation in each network. Each TIN was allocated to a particular bin with a consideration of providing the shortest distance. There was a consideration of road network's slope in a triangulated irregular network for providing the waste bin location. The slope and shortest distance criteria were considered for the handcarts which will be used to carry the waste from the waste bins. A record was prepared about the amount of waste generated in each bin with a description of waste carrying capacity of bin, type of bin and the waste lifting frequency. In the end consideration of the suitability of the bins for land use and repeating the above procedures for relocating the bin if found unsuitable for any criteria.

2.3.5 Results and discussion

The triangulated irregular network was presented to illustrate the allocation of bin for the solid waste generates in the network. The waste bin allocation on the basis of the command area is illustrated on the map. The type of waste bin its size, waste storing capacity, their waste clearance frequency and the transfer system was decided on the basis of waste generation and the location of the waste bins.

2.3.6 Critical views

The consideration of road network's slope in a triangulated irregular network for providing the waste bin location for the use of handcarts to carry the waste from the bins is a very good factor of consideration. It denotes the detailed level of observation and consideration of the user convenience factor. This point of consideration is a best example of a counter balance of the limitations of an area to use vehicle due to insufficient road width or even limitations in resources resulting in use of cheap handcarts or tricycles. In this model there was no consideration of separate bins for organic and non organic waste. Today the segregation of waste is considered as an important issue and waste management without the consideration of recycling is contradicted.

Other related paper regarding use of GIS technology :

2.3.7 Title of Paper : Development of Smart Solid Waste Technology Smart Solid Waste Management in New Capital City Amaravathi

Name of Authors: Kalyan Chakravarthi. G. et.al,

Name of Journal : International Journal of Recent Technology and Engineering (IJRTE)

Year : 2019

Finding : The Author presented the study on SSWM in Amravati. In cities with an aggressive population, there is no proper waste management system so there is a chance of spreading infectious diseases. Thus the author addresses various technologies which involve treating solid waste which includes radio frequency identification devices machine to machine, pneumatic system, IoT, plasma technology. From the summary of data collected from the tullur, rayapudi, velgapudi, nelapuda the solid waste management techniques are identified. From that one of the technologies is implemented. The traditional and conventional methods are compared based on the analysis using a mathematical model which is drawn from the quantity survey of gathering questionnaires from this which confirmed the advance techniques of solid waste management. Among the four methods, the author stated that based on the questionnaire carried out in the four villages for solid waste disposal systems pneumatic system has found best for the Amravati city.

2.3.8 Title of Paper : Integrated Waste Management of Smart City Gandhinagar",

Name of Authors: Harendra K.Vasava et.al,

Name of Journal : International Journal of Recent Technology and Engineering (IJRTE)

Year : 2019

Finding : The author explained smart city Gandhinagar SWM which is integrated. In this, the author focused on the reprocessing of waste and reduction of waste entering the landfill by treating the waste in the biogas plant. From 105 tons of waste 42tons of waste is treated. Gandhinagar city has an adequate SWM system. The waste is collected on the new concept which is introduced by the GMC. The door to door collection system is covering all the residential areas. The waste is collected on the scheduling basis of the working hour. In the evening time, the waste is transferred to a hydraulic euro III vehicle with a closed system. From there waste is carried to the transfer station to the treatment plant. In Gandhinagar, GMC has solid waste management facilities like the vermicomposting plant, refuse transfer station, biogas plant and open dumping site in the corresponding sector. Based on the waste generated in the city the waste is getting treated in biogas treatment plants. The author designed based on the biogas plant treatment according to what high energy will be generated and how much amount of waste can be prevented by entering into landfills.

2.3.9 Title of Paper : Use of the smart compost bin in Smart cities

Name of Authors: Tajne K.M et.al

Name of Journal : International Journal of Innovations in Engineering and Science

Year : 2019

Finding : The Author described the smart compost bin in Smart cities. This author explained how the smart compost bin acts as mitigation for the waste generation and which is a smart way for the reduction of waste. It also explained the characteristics and structure of the smart compost bin. The compost of waste can be used for agriculture purposes as a fertilizer which gives more growth and less pollution. Smart compost bin method is good practice keeps aesthetically good as from environment and economical perspective it is more beneficial compared to the existing method. The component of the smart bin is metal & detection of plastic, unit for composting and provision of fertilizer which is produced. The temperature, moisture content, & oxygen content are some parameters that are used for controlling the purpose of the composting process. And in the course of composting period temperature fluctuation is maintained. Some microorganisms are needed in order to make more successful and this system works totally due to solar energy. In order of recycling the waste contained organic matter back to the soil, it will improve the structure of soil along with productivity.

2.3.10 Title of Paper : Assessment of Solid Waste Management of Malegaon City

Name of Authors: Yakub Ansari, Prof. F.I Chavan, et.al,

Name of Journal : International Journal of Recent Technology and Engineering (IJRTE)

Year : 2017

Finding : In this article, 31 published studies on solid waste management were reviewed for their methodological and technological assumptions. Overall, research study has been providing a flexible framework to quantify environmental impacts of improper solid waste management. Solid waste management (SWM) has become an issue of increasing global concern as urban populations continue to rise and consumption patterns change. The health and environmental implications associated with SWM are mounting in urgency, particularly in the context of developing countries. While systems analyses largely targeting well-defined, engineered systems have been used to help SWM agencies in industrialized countries since the 1960s, collection and removal dominate the SWM sector in developing countries. However, urbanization, inequality, and economic growth; cultural and socio-economic aspects; policy, governance, and institutional issues; and international influences have complicated SWM in developing countries. This has limited the applicability of approaches that were successful along the SWM development trajectories of industrialized countries. The approach of corporation of Malegaon towards waste is only collection & disposed of it, no further treatment is given to non-decomposable waste as decomposed waste is composted with the method of vermicomposting. Also there is no approach towards revenue generation from waste. Waste collected from municipal region is not segregated. Waste collected from industry, hospitals, commercial complexes, institutes is disposed off on the same place.

2.3.11 Title of Paper : Implementation of spatial smart waste management system in Malaysia

Name of Authors: MF Omar, AAA Termizi, D Zainal, NA Wahap, NM Ismail, N Ahmad

Name of Journal : IOP conference series: Earth and environmental science

Year : 2016

Finding: Authors explained the implementation of smart waste management in Malaysia to improve the city management and to provide better services to the public towards smart city applications. This paper reviewed on MPS & MDKL waste management monitoring process. The ultrasonic sensor by virtue of IoT technology is manipulated by geospatial technology and intelligent sensor and for waste collection operator solid waste management provides a greater base into real-time monitoring work of waste by the local authority into establishing the service along enhancing cost and movement time. The main issue is regarding in which way into bringing to the local authority along competing for cost and low care price. the prevailing system, for limited apartment and condominium implementation is done based on inside the apartment waste chamber, the sensor device which is provided on the top of the bin and this paper also explained about the future recommendation, the implementation is done to the citizen as small IoT devices which are used for monitoring purpose and it also should provide in facial of each terrace house along with bungalow.

2.3.12 Title of Paper : “A Study On Waste Management In Bangalore City”,

Name of Authors: Arun Kumar H, PraveenaGowda, and Puttmurty,

Name of Journal : International Journal of Innovative Research in Science, Engineering and Technology,

Year : 2013

Finding: Authors studied smart waste management in the Bhubaneswar Nagar area of Bangalore city. The author aimed to focus the currently existing by monitoring and also concentrate on the financial analysis, potential issues arising in the area by fragmentation of generation of waste in respective areas. The target of the project comprises of 3R’s concept which means reduce, reuse and recycle. The analysis is done based on the secondary data from the analysis the segregation process is done based on the wet waste, dry waste. The segregated wet waste is collected from the resident and they were given to the neighbouring university GKVK as long as for purpose of research and manure and dry waste is recycled by ITC company and the remaining waste is transfer to landfill and author suggested smart bin technology, RFID, handwritten technology. From the current practices in Bangalore city which result in maximum revenue, recovery of resource, less expense in transportation also with less pollution.

2.3.13 Title of Paper : “Smart labels in municipal solid waste- a case for the Precautionary Principle,”

Name of Authors: Wager P.A, Eugster.M, Hilty L.M, Som.C,

Name of Journal : Environmental Impact Assessment Review,25

Year : 2005

Finding: Authors evaluated the RFID labels applications of potential impacts in the waste area. The valuable and toxic substances dissipation established recycling systems potential disruption, these are the major potential impacts that are considered in a proper sequence in case of which figure of measures are appropriated. These potential risk measures are considered for the precautionary principle. The precautionary principle founds in the forecast and curtails the potential risks beneath unpredictability conditions. This principle has been applied in much national protection for environmental protection and sustainable development.in this paper, the author has discussed the result of the precautionary principle in the application of the smart label of municipal solid waste. The valuable and toxic substances like few risks are dissipated by smart labels. By the use of smart labels and regarding composition these risks can be averted through precautionary measures. According to resource management and environmental protection, the precautionary measures should be enforced as soon as possible in order to troublesome inevitable improvement.

2.3.14 Title of Paper : Development of Smart Solid Waste Technology

Name of Authors: Uma Maheshwari , Dr.K Yogeswari

Name of Journal : International Journal of Innovative Research in Science, Engineering and Technology,

Year : 2019

Finding: Authors found that the conventional solid waste management existing system is not functioning properly as a result of the inadequacy of employees, convoluted in the solid waste management system and improper monitoring system. This paper discussed the work related to the smart technology in solid waste management by conducting various literature survey, SWOT analysis is done based on the literature survey. The smart technology involves the process from collection to disposal. A SWOT analysis will help to find the strength, weaknesses, challenges involved in the smart technology of solid waste management (SWM). The result of this analysis can find a better way to implement smart technology in solid waste management infrastructure

2.3.14. Title of Paper : RFID Application in Municipal Solid Waste Management System

Name of Authors: Abdoli, S

Name of Journal : Int. J. Environ. Res., 3(3):447-454,

Year : 2009

Finding: The author reveals some applications of RFID technology in Product self-management, with emphasize on municipal solid waste management as well as environmental implications of RFID. Broad usage of RFID tags on consumer products bears risks of dissipating both toxic and valuable substances, and could disrupt the established recycling processes. This causes a potential mid-or-long term risks with respect to resource management and pollution control. However, these risks could be avoided or mitigated applying precautionary principle in the early stage of development of RFID technology.

2.3.15 Other Related articles to use of AI and ML :

IoT with a machine-based waste management system focuses on waste disposal and improves the environment for health. -e intelligent waste collection and disposal is a major problem in the use of a smart city. Because the rapid development of a smart city and population increases daily waste, in the normal way, waste disposal requires more human resources and more time. It also damages the environment, social life and the atmosphere. Abdullah et al. and Talari et al. discussed a review of an online material-based waste management system . Monika et al. proposed a smart bin garbage collection system with Arduino UNO board with GSM module. But it does have limitations such as difficulty in repairing it, as well as extra collection time . Similarly, Kumar et al. a proposed dustbin using an ultrasonic sensor to continuously monitor the level of debris. It also ensures the immediate disposal of waste after reaching a certain level of waste in the dustbin . In India, Shyam et al. proposed a cleverly based dustbin in Pune using the IoT prototype. It analyzes IoT-based waste management, for example, nearby neighborhood searches, provincial development, genetic calculations, and molecular development strategies. Pardini et al. proposed a solid waste management system to collect waste information from other data [. Similarly, Bueno-Delgado et al. the proposed waste collection system uses efficiency in smart cities. It is widely used in rural development. But it does not provide clear results . Lozano et al. discuss line degradation and waste management system based on genetic algorithm to collect waste and assess the condition of the bins. But it does have a limit to the conversion of waste from bins to other devices. Therefore, it is difficult to implement a waste conversion program. Hannan et al. a proposed waste management system using a line-based robot to collect waste, but not for waste disposal . Popa et al. discussed how to collect food waste using RFID technology and transmitted over wireless networks. But this method is not suitable for a place far away to find a smart city. And in fact, it cannot be used in real-time applications . Cerchecci et al. discussed a hearing-based waste management program. But this function can only be evaluated on board but not in real time for a waste management system.

Proposed Methodology:

Waste filtering is important to provide a recycling process. There are many ways to filter out waste accurately indicating the cost and size of the product. The separation of resources includes the classification of generated waste and recycled materials. In this automated process the best use of technology and power to prevent the risk of human disorders and respiratory and skin diseases. We have suggested using the introduction machine learning algorithm here, which can drastically change simple strategies and success levels. The machine learning algorithm combines new and existing conditions and predictions to adapt to changing conditions. One of its major advantages is that it can integrate even the most unrelated and sensitive sensory information into the decision-making process. The machine is trained to detect glass, metal and plastic materials using different shapes, levels of corrosion, sizes, colors and different levels of contamination.

The major contribution of the paper is summarized as follows:

(i) Review on the smart solid waste management and its keyfactors.

(ii) A detailed explanation of existing waste managementsolutions and its drawbacks.

(iii) A classification of different machine learning algorithmsin smart city waste management systemand its countermeasures.

(iv) We present intelligent based waste management system with machine learning algorithm to collect and predict the waste accurately.

(v) Proposed method can be analyzed with different machine learning algorithm in terms of accuracy and time consumption.

2.4 CONCLUDING REMARK :

Available documents show that in India, a number of decision-making systems (DSS) have been developed and implemented in the municipal waste management area since the mid-'20s. Most of them talk about one or a few parts of the process. The development of a comprehensive and easy-to-use EDSS solid waste management system in the Indian regulatory and social framework seems to be very necessary and timely in order to fully realize the benefits of planned investments in the infrastructure and health sectors. The function of the conceptual framework of the proposed decision-making system, called 'AIMSWM' has been introduced. Concluding Remark of Literature Review :

From the above literature review we got the knowledge of how the applications of Geographical Information system(GIS) along with along with the use of Artificial Intelligence system can be used as a tool for proper waste management by means of analysis of the waste situation of the area.

3.0 AIM AND OBJECTIVE

3.1 AIM OF THE PROJECT

The GIS based model is designed to reduce the waste management workload to some extent by solving some of the present situation problems. The model will be implemented on the primary data of the case study area using GIS software. The analysis will be carried out on the study area data to get the analysis results. To provide an efficient solution for smart and effective waste management using machine learning (ML) and the Internet of Things (IoT) is proposed in this paper which is expected to reduce the waste management workload to a certain extent.

3.2 OBJECTIVE OF THE PROJECT

Any research is carried out for the attainment of certain intended objectives. Likewise, this master thesis has a general and well as specific objectives to be achieved at the end of the work. Therefore, the general objective of this thesis is to assess the solid waste problems and find software solution for optimal site selection for disposal in the study area.

- To study the current status of solid waste management in the case study area .
- Identify the economic values of solid waste in the town.
- Pointing out the main contributing factors affecting the solid Waste Management process in the town.
- Identifying conflicting interests among actors in collection, processing and disposal of solid waste products.
- To increase efficiency of the waste collection system through GIS based waste collection routes which will also monitor performance of waste operators through tracking of waste collection and transportation vehicles planning.
- Classification of waste using Artificial Intelligence. Here Machine is trained through machine learning algorithm to detect glass, metal and plastic objects using different shapes, degradation levels, sizes, colors and different levels of contamination.
- To provide operational guidelines for efficient municipal solid waste management system.

4.0 METHODOLOGY OF WORK :

This project would deal with, how Geographical Information System along with Artificial Intelligence system can be used as a decision support tool for planning waste management scientifically and efficiently

4.1 Data collection Methodology :

The following data will be collected from case study area:

- *(A) City and case study area maps :*

Maps will collected from the Municipal Corporation office . The raster images will be digitized to enter the spatial information on the maps in point, line and polygon features for the residences ,schools, hospitals, offices for land use by general survey .

- *(B) Waste bin location data :*

The location of the waste bins will demarcated on the case study area map.

- *(C) Shop waste generation data :*

Map of the study area will be used to mark the location of the shops. Waste generated in the shops will be divided into three categories i.e. composite , recyclable and mixed.

- *(D) Interviews :*

Interviews will be conducted in order to collect information and knowledge about the current solid waste management . Four sectors were studied: the government, the academia, the public and private companies.

4.1.1 Processing of collected Data using GIS model

The information and Data collected of different types and forms has to be transferred into the Geographical Information System (GIS) database. GIS can provide effective handling, displaying and manipulation of such geographical and spatial information.

4.1.2 Classification of waste using Artificial Intelligence System :

The machine learning algorithm can integrate even the most unrelated and sensitive sensor information into the decision-making process. Machine is trained to detect glass, metal and plastic objects using different shapes, degradation levels, sizes, colors and different levels of contamination which uses the smart waste bins fitted with sensors.

4.1.3 To provide operational guidelines for efficient municipal solid waste management sys tem.

4.2 DATA COLLECTION :

Data collection is an important work and it is the back bone of the project. Appropriate data is necessary for a proper analysis and this leads to derive accurate results. The database of the case study area is prepared on the basis of the information collected from different sources. The information of different types and forms has to be transferred into the GIS database. In this thesis the information was collected from different sources and was integrated to form a database of the case study area. The information gathered was quite helpful in the preparation of data. There were also some inadequacies in the information which were not sufficient enough to form a complete data. There was also requirement of some information which was not available and this was a limitation in the data availability. Some information was not sufficient to produce a good data format which was a limitation in the data collection. The process adopted in information collection and later incorporating it into the database such that it can be useful for the intended analysis is discussed below.

Municipal Corporation	Solid waste (Metric Tones)	Percent
Mumbai	8837.01	65.15
Thane	1061.34	7.82
Kalyan–Dombivali	969.59	7.15
Ulhasnagar	546.54	4.03
Navi-Mumbai	955.62	7.04
Mira-Bhayandar	612.26	4.51
Bhiwandi-Nizampur	583.02	4.29
Total	13565.38	100.00

Table 4.1: Solid waste according to municipal corporations

4.2.1 City and case study area maps

Maps were collected from the Mumbai Municipal Corporation, Mumbai. The maps were available in the form of blue prints. Usually the corporation office has an original record copy from which the blue print copy was developed. The Thane, Mumbai map was available on the scale of 1:32000 and had the information of city boundary, different areas, important landmarks, major roads, railway line and airport. The second map was a detailed map of case study area which was on a larger scale. It was of scale 1:2000 and covered an area of 2 sq. km. The detailed map had the information about the detailed road network, major buildings, religious buildings, cinema halls, market, landmarks and water stream. Both the maps marked with a grid and were scanned in A4 size images. Later these grid map images were imported in the Arc View 3.3 and joined together by mosaicing technique. Then the base map raster image of Thane, Mumbai was geo-referenced. The detailed map raster image of the case study area was then located on its position on the city map which can be seen in figure 5.1. Then the raster images were digitized to enter the spatial information in vector form. Different information was spatially located on the maps in point, line and polygon features. The case study area detailed raster map with vector data information in different features is seen in figure 5.2. The information about the schools, hospitals, offices and marriage halls was collected by general survey and the information from the local source like the area residents.

4.2.2 Land use data

The areas which are shown in the land use are the schools, hospitals and nursing homes, cinema halls, marriage halls and religious buildings. There was information of some of the land uses in the municipal map which is used as the base map. The land uses available on the map were the location of schools, cinema halls, vegetable market and major buildings. The other land uses which were required in the analysis and were not available in the map were collected from other sources. Those were the hospitals, nursing homes, clinics and office buildings. The maps being old, some latest land use information was also needed to be updated. There are two natural water streams passing through the case study area and those are demarcated in the municipal map.

4.2.3 Waste bin location data

This information was collected from the municipal office. The location of the waste bins was demarcated on the case study area map. These locations also include some open dumps which are presently in use for waste collection. But on a whole all were used for waste collection and are represented as existing bin location. The same information was used in the database.

4.2.4 Shop waste generation data

It was a complex job to collect the information regarding the shops and the type of waste generated by them. A simplified technique was adopted so that the waste generation trend of the shops can be assessed. For getting the data about the location of shops in the case study area, a map of the study area was used to mark the location of the shops. The shops in a row or a group were represented by a single line. This line represents group/number of shops (irrespective of the exact number of shops) at this location. The location of the group of shop was sufficient to spatially refer its position on the map. The second information was, the type of waste generated in the shops. For this the waste was divided into three categories i.e. composite (organic), recyclable (inorganic) and mixed (containing both type of wastes). Now as per these three categories the shops in the case study area were to be assigned the appropriate category as per the type of waste it generates. The list of total number of shops in the area was divided into three categories. The line representing the group of shops was assigned with the category of waste according to its waste generation type. If all the shops in the group generate recyclable or a composite type of waste, then it was assigned the category 'recyclable' or 'composite' on a whole. If there are shops which generate both type of waste in the group of shops, then that group was assigned 'mixed' category of waste generating group. This information was sufficient to have a basic idea about the type of waste generated in shops. The third is the attribute information which will form the attribute data giving the information about the spatial elements. For instance, for a group of shops in the map the attribute date of that group will posses the information about the category of waste generated in that group or any other land use.

4.2.5 Limitations of the data

The data information was collected from different sources and tried to incorporate in the GIS data base. There were some limitations in the data; it was related to both data type and data availability. All these limitations are discussed below; The maps available form the municipal corporation were old enough and does not have the information about the later date and changes. There can be more precession in the waste generation in the shops by having the exact information. But this requires a detailed survey conducted with exact number of shops and each shop represented by a point feature and attribute information about the category and quantity of waste generated in that shop. But the data which was available was for a group of shops so the quantity of waste generated by the shops cannot be evaluated. But the type of waste generated by a group of shops can be used to determine the requirement of the waste bin type in that area where the group of shops is located. The land use data of the hospital, clinics and nursing homes is available in a point feature. The point feature only demonstrates the location by a point and does not give the exact area of the land use. It would have been more convenient to have the boundary and area of the hospitals to have a precise analysis for waste bin proximity. There can be an analysis of the quantity and the type of waste generated in an area on the basis of population density, land occupancy and type of settlement. This could help in analysing the waste generation situation in a precise manner. But as there is no availability of detailed information of the population distribution, the quantity of waste generation cannot be related to the area density.

4.2.6 Type of wastes

We got an idea about the type of waste generated in houses. The content of waste thrown into the municipal waste bin is food waste, vegetable waste, yard waste. All these are of wet or semi wet type and the swept garbage comprises of soil, dirt and dust which is of dry type. There is sometimes usage of paper or cardboard in the household which also goes in the garbage. As it is used along with the food materials it gets dirty and semi wet in contact with food and vegetable waste. It is not practically possible to separate it from the food waste and usually it is less in quantity and can decompose with the other organic waste so it can be left as a part of organic waste which can decompose. As far as plastic and polythene items are concerned, though they are also less in quantity but still it is advisable to separate it from the organic waste before the final dumping of the waste to the landfill.

4.2.7 Storage of garbage

Regarding the waste storage, it is seen that 90%of residents use their personal house waste bins to collect and store the house waste and throw the waste into the municipal waste bin by directly emptying the garbage from their personal bins into the MWB. Whereas 10% use polythene bags to collect and store the waste and throw it along with the garbage. It is seen that 60% of residents keep the garbage for 1 or 2 days at their places and 25% keep for 2 to 3 days and only 15% keep it for 3 to 4 days. It is clear that mostly people do not prefer to keep the waste for long. A strong reason for this is that the domestic waste being damp in nature gets spoiled very fast thus starts producing foul-smelling and invites flies and insects.

4.2.8 Recyclable waste

About the recycling waste, usually the type of materials people sell to the waste buyers are glass, old books, newspapers, plastic bottles, polythene bags, metals, clothes, footwear and other such kind of waste. There are different categories of recyclable waste buyers in the market as per different categories of recyclable waste materials. The most significant point about the reselling market it that almost every recyclable material which has even a least resale value is been utilised. This is a positive thing in the waste system that, somehow the system is successfully promoting the waste recycling. Mostly the citizens are adjusted to the recycling pattern and find it feasible to separate the waste at their places itself. There is one more general observation regarding the response of different income group people regarding the resalable waste. It is observed that there is a positive attitude towards selling the recyclable waste to the waste buyer's .The lower and middle income group people prefer to sell waste, as they get returns out of it. In higher income group, citizens might not be much interested in the returns but they usually have servants for the household work who often take initiatives to selling the recyclable waste as it could make some additional income for them. Regarding the storage of the recyclable waste, it is observed that, 40% of the people have been keeping the resalable waste for a week's time, 20% have been keeping it for 2 weeks and next 20% have been keeping it for 3 weeks. The left 20% keep it for more than 3 weeks. This type of waste is absolutely dry and can be kept for long without getting spoiled provided that there is no storage inconvenience to the user at its place. Usually people store this kind of waste materials in their storage and give it to the waste buyers whenever they come to buy the waste. There is no other inconvenience in keeping it for long.

4.2.9 Convenient distance

According to (CPHEEO 2000) the maximum distance between a household to a waste bin should be 250 meters. This limit is set to take care of the public convenience. So keeping this in mind the option in the questionnaire were given from a range of 50 meters and up to 250 meters with a regular difference of 50 meters. These choices were given with the intention to get the exact preferences of the citizens and it worked. The preference of majority of people was achieved. Almost 70% had given a preference to 100 meters as a convenient distance for them from their places to the municipal waste bins. Whereas 20% wants it to be within 50 meters and only 10% feel that it can be up to 150 meters. Majority of citizens prefer to be nearer so it is advisable to provide a bin within a reach of 100 meters for all the citizens. It might be less than this for many houses but it is more important that it should not be more than 100 meters for all the residents. Those who are having a bin more than 100 meters away should be considered for providing this facility within a convenient distance.

4.2.10 FRAME OF GUIDELINES

It was very important to frame the guidelines before the design of the model to get a defined direction to the objectives. The study of the previous models was helpful to learn different methods used for the waste management in different situations. The availability of data is also an important factor to decide the working methodology. Availability of limited data or unavailability to some data is a restriction in the design. It becomes a constrain criteria which needs to be considered and design the model to achieve the objective with the limited data. Some alternative has to be worked to get to the required solution. The frame of guidelines was prepared on the basis of the extract from the example studies and the existing waste situation in the city. The guidelines are discussed under the respective headings and the reason behind the consideration of those points is also discussed.

4.2.11 Economy criteria consideration

Economy does play a major role in any assignment or a work proposal. The budget constrains have to be considered and in the present situation, the new proposals in the city SWM should be such that it does not contain heavy capital investments. Keeping the existing system in its maximum functionality and at the same time suggesting some new additional functions and corrections which overall intend to solves some major existing waste management problems. The new proposals should come across with some ways to generate revenue for the system without any compromise with environmental or health issue. This economic support would contribute in better maintenance of the system and further make ways of affordability to buy better technologies for the system. So the design of this model is proposed by taken into consideration the present budget constrain factors.

4.2.12 Flexibility in model

Keeping in consideration the changing nature of the city dimension, land use and diverse public nature it is advisable to keep flexibility in the model design. There is sometimes change in the bin locations, nature of waste generation due to change in land use or establishment of different land use in an area, and these changes are a part of the system. A model having the margin of flexibility for consideration of these uncertain factors would be much suitable for a long term.

4.2.13 Identification of recyclable waste generating areas

It is very important to extract the information from the existing situation about the type of waste generated in different areas. So the areas which indicate the generation of recyclable waste can be proposed with the separate bins. It is quite difficult to segregate the inorganic dry waste after it gets mixed with the wet organic waste comprising of domestic, food and other waste. According to statistics of the National Solid Waste Association of India, in the composition of MSW of Thane, Mumbai the major content of the waste is of moisture content (25%) and organic (35%) i.e. 60% of the total waste and the remaining is the other inert material (40%). From this 40% we are considering the availability of recyclable waste. It is always advisable to utilise the recyclable waste as it helps in saving both environment and economy. “The net saving in environmental releases and energy consumption released at the manufacturing facilities that use recycled material instead of virgin materials are also required to evaluate an SWM strategy that recovers recyclables.”(E. Solano& et. al., 2002). It is also important to see the environmental effects of the waste disposal like there has been a new thing come up regarding the yard waste disposal. According to studies by B. R. Lerner., 2002, in yard waste the grass clippings should not be thrown in the waste but left on the lawns as they decompose soon and act as manure for the lawn growth. “The clippings will return some nutrients back to the soil, reducing fertiliser requirements.”(B. R. Lerner., 2002). This waste is difficult to decompose with the waste. “Although this waste is biodegradable, landfills do not get the oxygen and water needed for breakdown.” (B. R. Lerner., 2002). All these findings direct us to utilise and bring recycling into practice as much as possible. As information about the type of waste generated in not spatially referenced, we have to extract this information with the help of the type of land use of the area and this can be done using geographical information systems. The extraction of this piece of information from the land use type would be one of the tasks to be achieved in the proposed model. Though it is not possible to achieve the precise information about the exact location of the waste type generated, but the amount of information which can be achieved could be helpful in proposing a revised waste management system. There is no need to remove the existing bin location, as it is the requirement of the city, which is why they are there. What is required is to provide some additional bins for the collection of recyclable waste. And to remove or relocate only those bin locations which are not suitable or are a threat to the public health and environment. The new model would help to decide the areas which are in need of a recyclable waste bins in addition to the existing regular (organic) waste collection bins.

4.2.14 Waste categorisation

The waste can be divided into many waste categories but in the proposed model the waste management is considered in Indian context and conditions. It was found feasible to categorise it in two categories. The present situation in many cities is such that there is no segregation of waste at all. The situation of direct dumping of the waste without proper inspection and separation leaves a serious impact of environmental pollution causing growth in health related problems. The small contribution in waste segregation is done by the recycling industry and that too for the resalable waste. No doubt this is a very big contribution from the recycling industry which is reducing a lot of waste from going to the landfill and on the contrary providing a means of livelihood to many people by getting them involved in the waste recycling business. It was found suitable to divide the waste into only two categories for the municipal waste because it was satisfactory to handle the present situation to manage waste in a categorical form and reduce the waste from going to dumping yards. A big switch on to a new trend cannot be made at ones with too many implementations.

4.2.15 Waste categorisation for shops

There are many kinds of shops in the city and most of them generate some or the other kind of waste. It was a bit complicated to spatially represent the type of waste generated in every shop. So it was tried to categorise the shops according to the type of waste it generates. This was easy to collect the information in a categorised form. For this the methodology used was, a list was prepared of type of shops in the city and it was divided into three major categories according to the type of waste generated in them viz.

composite waste, recyclable waste and mixed type of waste which contains both composite and recyclable waste. Given bellow is the categorised list of shops;

Table 4.2 : Categorisation of shops according to their waste generation type

Organic (composite) waste generating shops	Recyclable waste generating shops	Mixed waste generating shops
Green grocery	Stationary	Bakery
Dairy	Hardware	Restaurant
Meat/beef	Garment	Cigarette
Fish/chicken	Electronics	Grocery
Lunch home	Cutlery	
Tailoring	Photo studio	
	Medical	
	Cassette	

It is seen that, every shop generates a particular type of waste and it is dependent on the materials in which the shop deals with. For example a stationary shop generates the waste which comes out of stationary goods like paper, plastic, and other packing material. All this can be categorised in a category of recyclable waste, nothing is composite or organic in this waste. In the similar way hardware, electronic or a garment shop also generates only inorganic waste which is absolutely recyclable. This categorisation was convenient to analyse the waste generation tendency in the shops of the case study area.

4.2.16 Waste bin type

It is observed that many of the problems arise due to the open type of waste bins. In the existing system, from the total waste generated and the total number of waste bins we have analysed that, the average quantity of waste generated in a bin comes around 185 kg/ bin. And the waste carrying capacity of the bin is 375 kg. So in general it can be assumed that the waste generated in the city per day is half of the waste carrying capacity of the total number of bins. But as there is an uneven amount of waste produced in the city this can not be considered that a bin collects the waste to its full capacity in two days. There might be some bins which get filled daily or even take less time. If we consider the adequacy of the waste carrying capacity and the number of bins then it is quite perceptible that there is no shortage in the size and carrying capacity of the bins. It is recommended that waste bins of the same capacity will also be sufficient but it is quite necessary that the bins should be such that the waste is covered all the time and is not accessible to animals and rag pickers. As there is a proposal for new type of bins then it would be appreciated if the bins of greater capacity are used. Because in future it is quite expected that there will be an increase in the waste generation and it won't be a wise suggestion to again change the bins due to inadequacy in its size. The other important factor is that, if the bin is of more waste storing capacity then the waste collection frequency can be reduced which will save expenses of frequent collection trips. It is often see that there is sometimes objection from the residents or proximity dwellers about inconvenience due to the waste bin. This problem can be dealed to some extent by providing a closed bin so there are minimum chances of stray animals, foul smell and bad aesthetical appearance around the bin. Another option which will be proposed in the model is the installation of new recyclable waste bins in some areas. For the allocation of the recyclable waste collection bins, the location is preferred to be close to the existing municipal waste bins. This would make it convenient for users to know about the placement of the recyclable waste bin and it is more practical to use. It is seen that at places where segregation bins are placed, people bring their waste to the bins and separate it at the waste bin before dumping it and it seems to be feasible also. So in the analysis whichever area demands the requirement of a recyclable waste bin should be provided with a recyclable waste bin next to the organic waste bin.

4.2.17 Land uses for consideration

Usually it is observed that, if a resident is facing some problem due to the waste bin proximity, then he makes complain to the concern authority and the location of the waste bin is removed from his proximity and changed to some place where it does not causes inconvenience to some other resident. In case there is again a complaint then the matter is again taken into consideration. This is a normal routine to find the appropriate location for a waste bin until a suitable place is found where it meets the terms of 'NIABY' criteria. Often suitable location is found by this trial option. But there are some land uses like schools, hospitals and religious buildings where it would not be advisable to make such trials by placing the bins in close proximity. There are certain reasons for which it is recommended to be sure enough that these land uses are considered in advance while locating the bins. These land uses are related to sensitive issues like health and sentimental values of the citizens. So these land uses are considered for the inconvenience due to proximity of the waste bins and should be made free from the waste bin proximity. The situation being such that due to dense land use in the city, much distance can not be demanded for buffer for a land use to the waste bins. A distance of 20 meters is suitable to maintain a distance from municipal waste bins and open dumps to these land uses. This distance can act as barrier in transfer of odour and flies form the garbage.

4.2.18 Positive points of the proposed model

As the model proposes the provision of separate bins for the recyclable waste generating areas, there would be a reduction of certain amount recyclable waste from going into the organic waste bins. This makes the waste free from the impurities which cause threat to the environment. Providing recyclable waste collection bins only for the required areas is a good idea to save the surplus expenses of providing bins to all areas irrespective of their waste production type. There is adaptability in the model for a correction. If some error is observed in the data or the methodology of data collection, it can be refined or fine tuned in the same model without any major changes in the model. This adaptability for corrections and refinements in data or the process makes it flexible for further making the model more refined as per the future requirements. Permissibility: The model can be used for different regions with some changes made to it according to the local area conditions and constrains. For example, a proximity buffer will be used in the same way as in the case study area, but changing the values of the 'buffer distance' as per the local guidelines. The functionality of the model will be the same in all cases. It can be used in for a broader as well as detail analysis as per the availability of the data.

5.0 Theoretical contents

5.1 GIS WORKFLOW MODEL :

This model is designed for proposing a system which could reconsider the existing bin locations in the city and providing some better alternatives in allocating and relocating the existing and the new proposed waste bins. The proposed amendments in the system through this model would reduce the waste management workload to some extent and solve some of the present situation problems. Figure 7.1 demonstrates the work flow pattern of the proposed GIS model. This model is divided into four key components which are primary data, analysis, functions and results. These key components explain the further detailing of the contents in them.

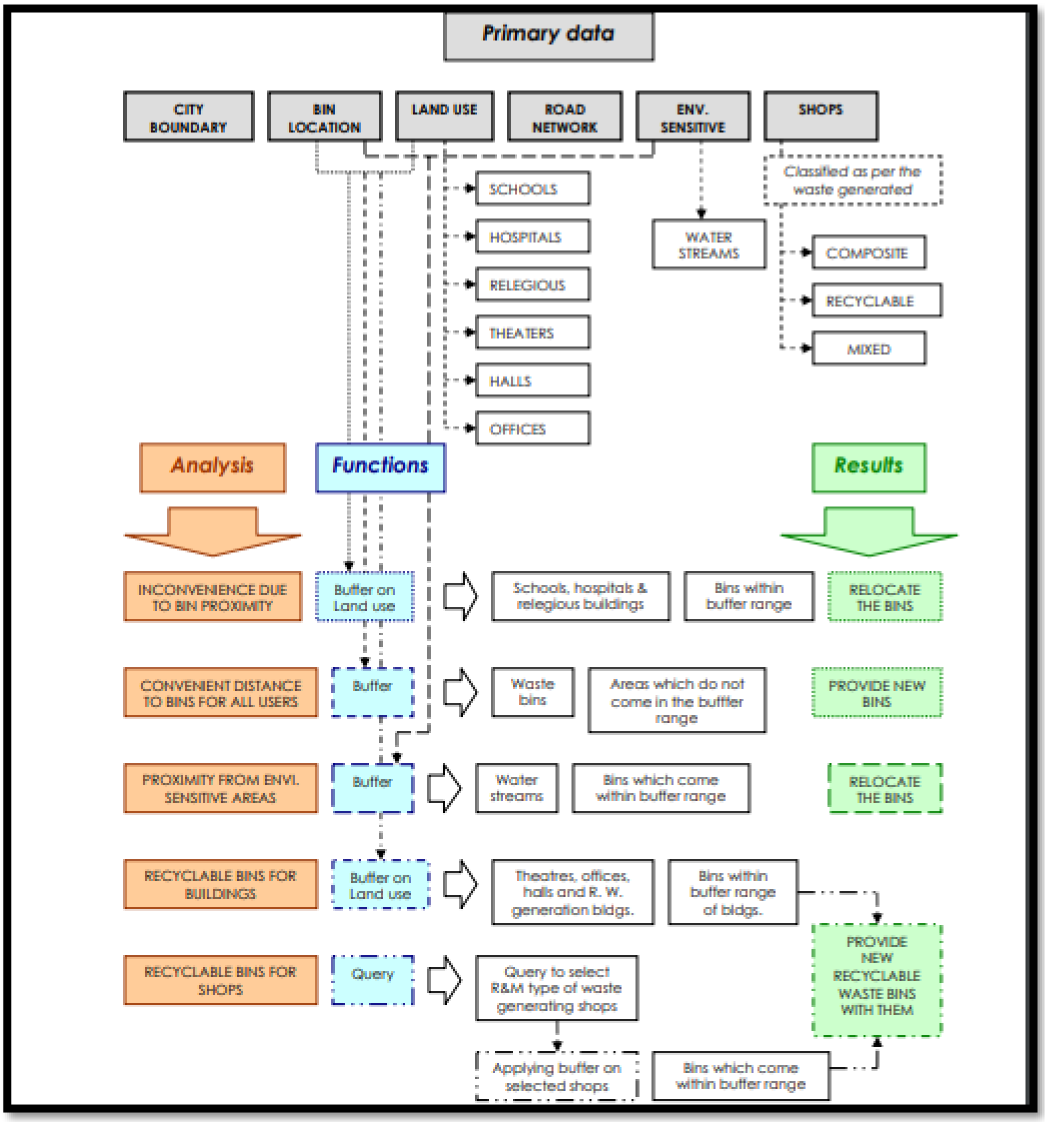
5.1.1 Primary data

The primary data comprised of different map layers of the case study area. The layers are boundary (base map), bin locations, land use, road network, environmentally sensitive areas and shops. The primary data has both spatial and attribute information.

- The bin location includes the location of both existing bins and the open dumps. These are represented in point features.
- The land use includes the locations of different buildings in different layers. They are schools, hospitals, religious buildings, theatres, marriage halls and offices. The land uses are represented in polygon and point features.
- This layer shows the road network of the case study area which is represented in line feature.
- The environmentally sensitive areas are two natural water streams which are represented by line feature.
- The shops are represented by a polygon. Each polygon represents a group of shops and there is a classification of all the shops in three categories which is based on their category of waste generation.

5.1.2 Analysis

The model covers five analyses which are to be made on the available primary data. These analyses are proposed for suggesting some improvement in the existing waste management system. The results of the analysis made on the available data will help as a decision support in planning the allocation of new recyclable waste bins and relocation of the existing bins whose presence at that location is causing inconvenience to the citizens and also risk to the environment. These analyses are discussed below under separate headings.



[Fig.5.1: GIS workflow model]

5.1.3 Inconvenience due to waste bin proximity

There are certain areas which need to be kept away the areas from the dust bin. So this factor will be analysed for existing bins and it would be also a guideline for proposing new waste bin in future. This analysis will cover the factor of inconvenience to a particular category of land use due to the proximity of municipal waste bin. The land use like schools, hospitals and religious buildings are preferred to have a considerable distance from the waste bins. For this, a buffer analysis of 20 meters will be carried around the three land uses i.e. schools, hospitals and religious buildings. In case of hospital buildings the data available was only the point theme representing the locations of hospitals and clinics where as in other land use we had a polygon feature to represent the whole building area. So for this analysis, the buffer will be created in three layers of 10 meters each which will make a total buffer of 30 meters. This would provide a margin of considering the first band of 10 meters buffer as the hospital building area and left two bands of 20 meters can be used for analysing the proximity.

5.1.4 Convenient distance to bins for all users

It is seen that seen the preference of majority of people for a maximum convenient distance for a waste bin from their places is 100 meters. For this analysis a buffer will be created around all the waste bins of the study area. The areas which come in the buffer zone will are within the convenient distance to use the bin, so these areas need not have to be considered for any changes in the bin location or allocation of new bins. The areas which are not in the buffer zone have to be considered to be having an inconvenience in using the waste bins due to long distance from their places. So these areas need to be considered for providing with new waste bins which will be at a convenient distance to those areas.

5.1.6 Recyclable bins for buildings

For selecting the nearest located waste bin to a building from the selected bins, the buffer can be applied in bands of different distances. This will make it convenient to make a comparison between more than one bin in a close proximity of a building. The closest placed municipal bins to those buildings can be suitable for providing new bins along with the existing municipal waste bins.

5.1.7 Recyclable bins for shops

This was intended to achieve two aims; to have an idea about the requirement of recyclable waste bins in the areas and to minimise the amount of waste going to the dumping ground. From the groups of shops those groups have to be identified which generate recyclable and mixed type of waste. So these can be identified by placing a query to select 'Recyclable' and 'Mixed' type of waste generating shops from the shops category. This will highlight the required groups of shops. These shops require recyclable waste bins to dump their recyclable waste. For locating recyclable waste bins for these shops the nearest municipal bins to every group of shops should be selected. This can be obtained by applying a buffer around the shops which are selected from the query results of recyclable waste generating group of shops. Similar to the recyclable waste for buildings, for selecting the nearest located waste bin to a group of shops, amongst the selected bins, the buffer can be applied in bands of different distances. This will make it convenient to make a comparison between more than one bin selected in a close proximity of shops. The closest placed municipal bins to shops can be suitable for providing new bins along with the existing municipal waste bins.

5.2 Machine Learning and IoT-Based Waste Management Model

The most effective solution to overcome the problem of environmental pollution is the use of the Internet of Things- (IoT-) and machine learning- (ML-) based waste management system [5]. These technologies can provide real-time information about the waste and provide an optimized path for the waste collection trucks, reducing the cost and time for the overall process. The issues faced by current waste management systems are improper scheduling; that is, the waste collectors do not know that they had to pick the waste. Although human interference is equally essential in collecting, transportation, and efficient waste disposal, the sensors are connected to the microcontroller . Hence, they will provide real-time information regarding the dumping grounds' waste index and the level of waste of the dustbins.

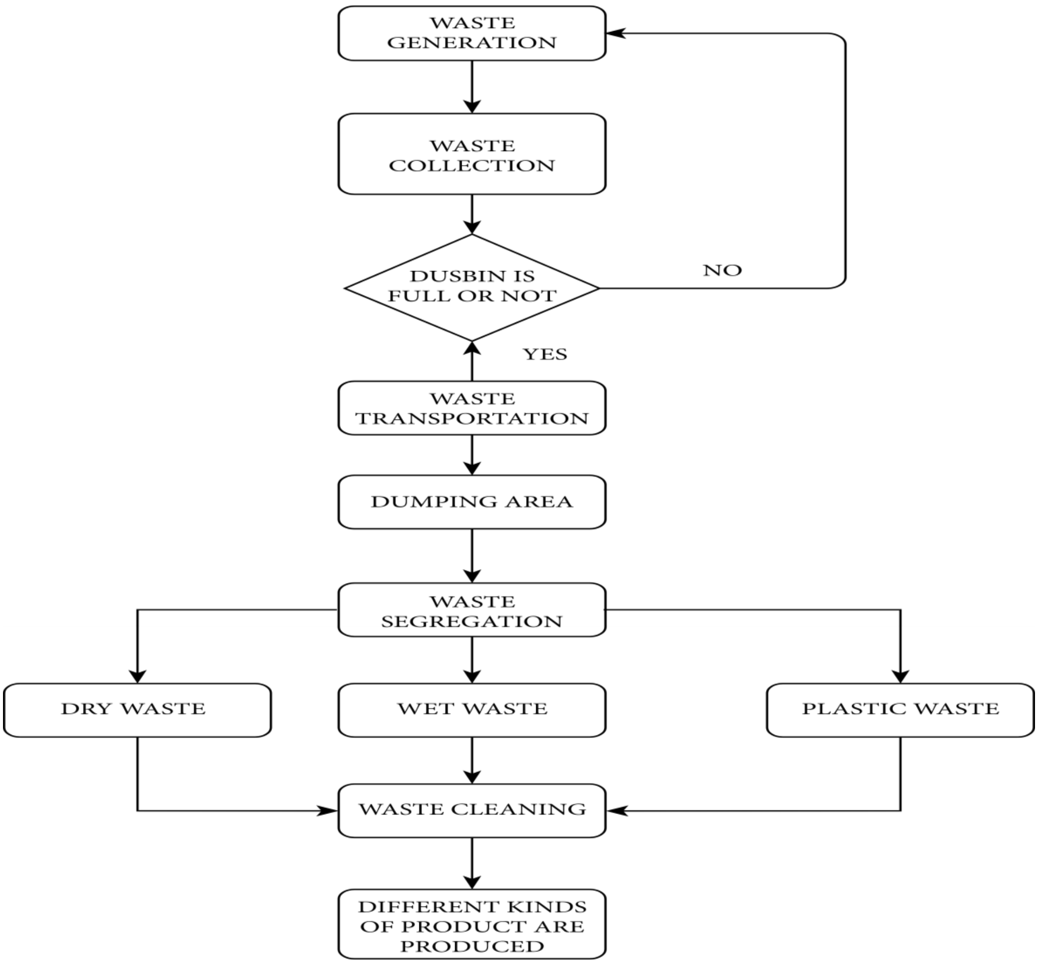


Fig.5.2 Flowchart For Smart Waste management

The Global Positioning System employs satellites to determine a vehicle, person, or other assets' precise position and records the asset's position at regular intervals. The trucks' details are then forwarded to the data centers with a remote correspondence interface. With the help of the tracking system, the authorities of a waste management organization can keep track of their vehicles. Ultrasonic sensor ranges from 2 cm to 400 cm measurement function of noncontact. Moisture sensors are also used to detect whether the waste is wet or dry. A mobile app is developed to store the history of the driver and various records related to waste. In this application, we also used image processing to measure the waste index of a particular dumping ground. The waste index can be low, medium, or high

Machine Learning (ML) refers to a significant function of Artificial Intelligent (AI) that allows a system the ability to learn and make the decision automatically without being explicitly instructed. Machine learning is a scientific study of some statistical models and algorithms. Due to offering the most exceptional features in computing, the popularity of ML has reached the highest peak. The convolutional neural network (CNN) is a momentous class of deep neural networks, more specifically, deep learning. CNN presents tremendous progress in image recognition. In general, they are applied to evaluate visual imagery and often worked beside the image classification.

On the other hand, the Internet of things (IoT) refers to a system of interconnected devices, digital or often some analog machine that enriches the ability to transfer data over a network beyond demanding human to computer interactions. A statistic on IoT (FUSON, 2020) estimated that average up to 127 new IoT devices being connected with public networks every second. Following the speedy growth, 328 million things are being connected every month.

The proposed system implements a smart system where users can take necessary precautions on the waste management system. The contributions of the above in waste management are as follows:

▪ A unique way to combine two technology namely IoT and deep learning paradigms is to ensure an optimal solution in the field of garbage management.

▪ An intelligent way to classify bio waste and non-bio waste through image classification using deep learning.

▪ An architectural development process of smart trash box using ultrasonic sensor, load measurement sensor, and micro-controller.

▪ A smart way to monitor waste in real-time conducted by Bluetooth communication for short-range, and IoT technology for long-range using.

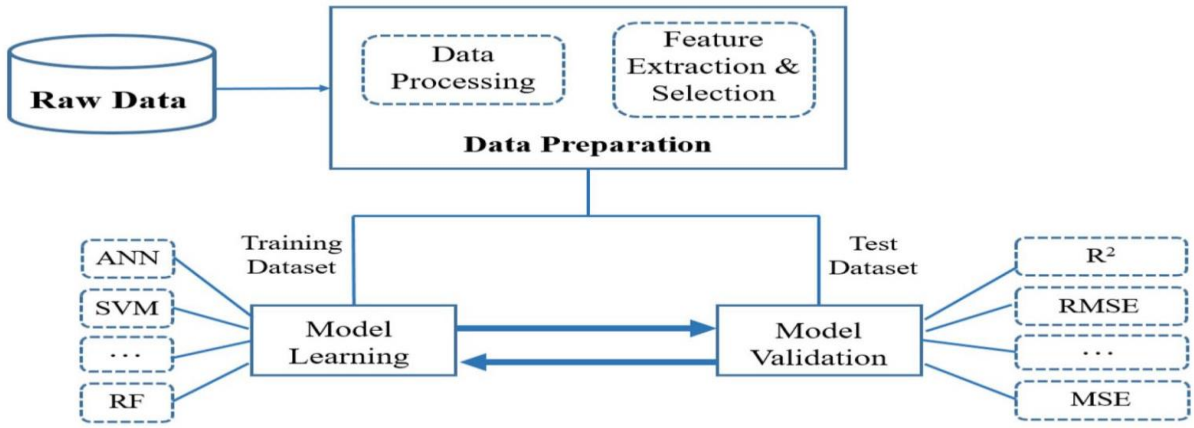


Fig. 5.3 Schematic diagram of ML workflow

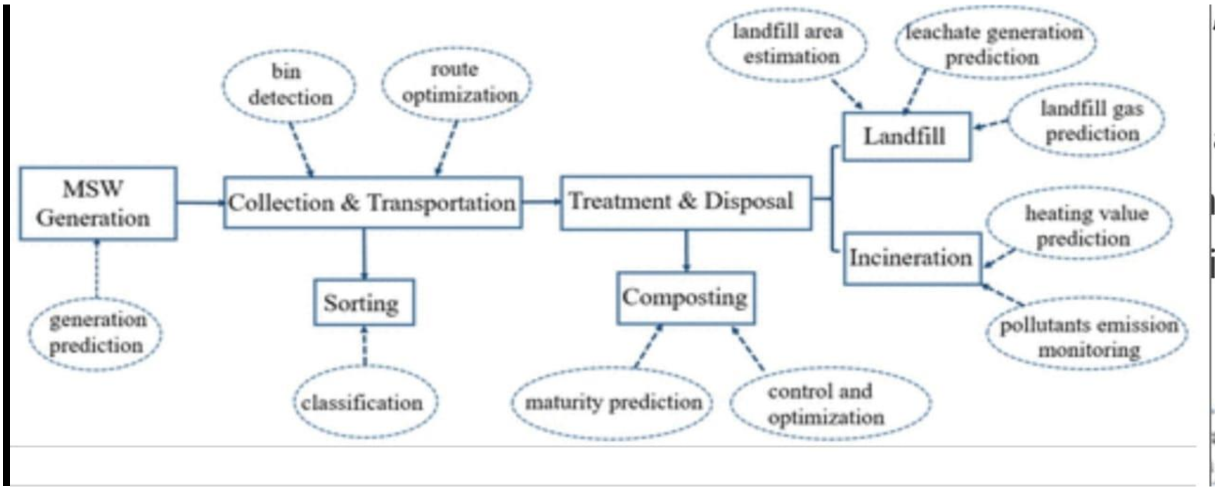


Fig.5.4 Schematic diagram of application of ML algorithms in MSWM

5.2.1 Application of ML algorithms in MSWM :

5.2.1.1 Waste generation prediction :

Reliable prediction of MSW generation is very important because it can provide data support for urban environmental planning, operation, and supervision and can aid in developing reasonable implementation plans for waste collection, transportation, and treatment (Oguz-Ekim, 2021). Therefore, MSW forecasting is the basis for waste management. Considering the different algorithms used and their application in different countries or regions, Table below provides a summary of the ML methods used to predict MSW g According to the articles reviewed, different ML algorithms such as ANN, SVM, and ANFIS, have been used to build the prediction model, and factors such as weather data and demographic and socioeconomic data are often chosen as input features. Among them, ANN is the most commonly used method, but its performance is affected by data over-fitting, local minima, and poor generalization (Abbasi and El Hanandeh, 2016).

Table. 5.1 Summery of ML algorithms for MSW generation

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Table 2. Summary of ML algorithms used to predict MSW generation.

Input feature	Output	Forecast period	Algorithm	Data size	Performance evaluation (Best model)	Scale	Advantage	Disadvantage	Reference
Urban form, demographic and socioeconomic, seasonality related (31 input parameters)	Weekly municipal waste generation in New York, USA	Short-term	GBRT, ANN	-	R^2: 0.87 RSME: 0.034 (GBRT)	Building	Analyze feature importance	Accuracy is not very high	Kontokosta et al. (2018)
Historical weekly waste generation(8 input data, windows size of 8weeks)	Weekly household waste generation rate in Herning, Denmark	Short-term	LSTM, ANN	-	RSME: 0.5 (LSTM)	Household	Use multi-site models to increase amounts of historical data	Only choose ANN as ML comparison model	Cubillos (2020)
Education, occupation, income, house type (4 input parameters)	Weekly plastic waste generation rate in Dhanbad, India	Short-term	ANN, SVM, RF	120	R^2: 0.75 RSME: 9.53 (ANN)	Household	Predict a specific component of MSW	Low accuracy	Kumar et al. (2018)
Population, formally employed, unemployed and number of family units (4 input parameters)	30years MSW generation in Johannesburg, South Africa	Long-term	ANN, SVM	30	R^2: 0.99 (ANN)	City	High accuracy	Easy to overfitting	Ayeleru et al. (2021)
Fraction of population over 45years, median personal income, employment rate, fraction of owned dwellings (8 input parameters)	Annual MSW generation in Ontario, Canada	Mid-term	ANN, DT	1553 (MSW-Census) and 1867 (Bluebox/ paper-Census)	R^2: 0.72 (ANN)	City	Use feature selection techniques	Low accuracy	Kannangara et al. (2018)
Population, solid waste collection frequency, maximum seasonal temperature and altitude (4 input parameters)	Seasonal MSW generation rate in Fars province, Iran	Short-term	ANN	80	R: 0.86 RMSE: 68.32	City	Use regularization to prevent overfitting	Lack of comparison with other ML algorithms	Azadi and Karimi-Jashni (2016)
Waste generation in past twelve month	Monthly MSW generation in Logan, Australia	Short-term	SVM, ANN, ANFIS, KNN	-	R^2: 0.98 RMSE: 175.18 (ANFIS)	City	High accuracy	Lack of comparison with other papers	Abbasi and El Hanandeh (2016)
Socio-economic parameters such as GDP population, condition of public infrastructure construction (7 input parameters)	Annual MSW generation in three regions of China	Mid-term	ANN	171, 130, and 48 for each region	R^2: 0.92 RSME >50	Region	Evaluate the effect of each predictor	Lack of comparison with other ML algorithms	Wu et al. (2020a)
GDP, rain, maximum temperature, population, household size, educated man, educated women, income, and the unemployment rate (9 input parameters)	Monthly and Seasonal municipal waste generation	Short-term	RBF-ANN, SVM, ANFIS	252	Monthly R^2: 0.68 RSME: 0.12 Seasonal R^2: 0.85 RSME: 0.07 (RBF-ANN)	City	Make feature correlation analysis	The accuracy is not high	Abbasi et al. (2019)
GDP per Capita, domestic material consumption, resource productivity (3 input parameters)	Annual MSW generation in 26 European countries	Mid-term	BPNN and GRNN	-	R^2 range from 0.798 to 0.843	Country	Provide prediction for countries at different economic levels.	Lack of comparison with other ML algorithms	Antanasijevic et al. (2013)

5.2.1.2 Waste collection and transportation :

The MSW collection and transportation system, as a hub connecting the source, final disposal, and resource recovery management, is the key to ensuring the normal flow of urban material and energy. On the one hand, the rapid increase in the generation of MSW has led to the failure of back-end treatment. On the other hand, the operation scope of MSW collection and transportation systems increases rapidly, and the complexity of the management also increases accordingly. Therefore, optimizing the collection and transportation route of MSW can effectively reduce transportation costs and improve operational efficiency.

5.2.1.3 Waste bin detection :

Waste collection faces problems of high transportation costs, and trucks often visit waste bins that are only partially full, which is an inefficient use of resources (Pereira Ramos et al., 2018). Many factors can affect waste accumulation, so it is difficult to predict the fill levels of waste bins. To improve the efficiency of waste collection, several studies have applied ML algorithms to realize waste bin detection, which can be regarded as a classification problem. Hannan et al. (2014) used an ANN with a Hough transform model or Gabor wavelet filters to classify the level of solid waste inside the bin, and the output was divided into five classes: empty, medium, full, flow, and overflow. Combined with gray-level co-occurrence matrix feature extraction methods. ML methods improve the classification accuracy, and intelligent detection of waste bin levels can reduce the driving distance of trucks, which could promote money savings for the management agencies, and reduce carbon dioxide emissions (Vecchi et al., 2016).

5.2.1.4 Routing optimization

The cost of waste collection and transportation accounts for 60%–80% of the total waste management system costs (Wu et al., 2020b), so optimizing the route of vehicles for waste collection and transportation can save time, reduce the running distance, vehicle maintenance cost, and fuel cost, and can also effectively arrange vehicles and allocate human resources. A few studies have applied ML algorithms to waste collection routes. Hoang et al. (2019a) combined a time-series ANN nonlinear autoregressive model with geographic information system (GIS) to analyze the effects of changes in waste composition and density on truck route optimization. For example, Ferreira et al. (2017) developed an ANN model to predict the collection frequency for each location, which can reduce unnecessary visits.

5.2.1.5 Waste classification

Waste classification is a scientific management method for effective waste disposal. Through classification, useful materials are recycled and utilized, and the quality of waste is improved, which is convenient for landfill or incineration to promote treatment that yields fewer risks to human health and the environment. Traditional waste classification mainly relies on manual selection (Huang et al., 2020a), which is inefficient, and with the development of artificial intelligence, many ML algorithms have been proposed to improve the accuracy of recyclable MSW identification (Liu et al., 2020; Ping et al., 2020). In recent years, CNNs have achieved remarkable results in image classification. Therefore, by taking pictures of MSW, the CNN can automatically identify different types of waste. Table 3 summarizes several CNN models used for the intelligent classification.

At present, various CNN architectures have been used (e.g. VGGNet, AlexNet, ResNet, and DenseNet) to build the MSW classification model, which has high accuracy.

However a challange that CNN has, a large number of parameters, and the training process requires considerable resources and time; therefore, transfer learning has been used to share the trained model parameters with the new one to improve and optimize the learning efficiency, which is the state-of-the-art algorithm for waste classification .

Table 3. Summary of some CNN-based models used in MSW classification.

Model	Classification output	Data size	Accuracy (%)	Advantage	Disadvantage	Reference
CNN (VGGNet, DenseNet and NASNetLarge)	6-classification: paper, glass, metal, plastic, textile, and organic waste	TrashNet (2527 images) and manually collect (5000 images)	96.5 and 94	Combine different candidate classifiers to improve accuracy	Limit amount of data	Huang et al. (2020a)
CNN (Improved DenseNet)	6-classification: cardboard, glass, metal, paper, plastic, trash	TrashNet + data augmentation (10,108 images)	99.6	Optimize fully connected layer of CNN	Lack of comparison experiments	Mao et al. (2020)
CNN (Inproved ResNet)	6-classification: paper, glass, metal, plastic, textile, and organic waste 3-classification: organic, inorganic, medical waste	TrashNet (2527 images) and internet resources (5904 image)	94 and 98	Compare the classification accuracy of multiple models	Limit amount of data	Vo et al. (2019)
CNN (Improved DenseNet)	6-classification: cardboard, glass, metal, paper, plastic, trash	TrashNet (2527images)+data augmentation	81	High efficiency	The accuracy is not high	Bircanoğlu et al. (2018)
AutoEncoder + CNN (AlexNet, GoogLeNet and ResNet)+ Ridge Regression +SVM	Organic or recyclable waste	Open-access dataset (25,077 waste images)	99.95	High accuracy	High complexity	Togacar et al. (2020)
CNN (AlexNet)+MLP	Recyclable or the others	Manually collect (5000 images)	98.2 (fixed orientation) 91.6 (random orientations)	Higher accuracy than using CNN alone	Lack of comparison experiments	Chu et al. (2018)

Accuracy refers the ratio of the number of correctly classified samples to the total number of samples.

Table. 5.2 Summery of CNN based models for MSW classification Waste treatment and disposal

5.2.1.6 Composting :

Composting is a valuable method for organic waste treatment (Walling et al., 2020). Organic matter is the main fraction of MSW; therefore, composting can be considered a cost-effective option for MSW disposal. After composting, MSW becomes a hygienic and odorless humus, realizing the key aspects of harmlessness, waste reduction, and recycling. ML algorithms can help model the complex processes that occur during composting, such as maturity prediction, parameters control, and optimization (Table 4).

Table 4. Summary of ML algorithms used in MSW composting.

Application	Algorithms	Data size	Input feature	Output	Performance evaluation	Reference
Maturity prediction	Wavelet Neural Network	500	High temperature duration, moisture content, volatile solids, the value of fecal bacteria and germination index (5 input parameters)	4-classification: full maturity, preferable maturity, general maturity, immaturity	MSE: 0.066	Gao et al. (2007)
	ANN	1536	Color and texture features (input parameters range from 14 to 49)	2-classification: early maturity or not	Classification error: 1.56%	Kujawa et al. (2014)
	CNN	1312	RGB images	2-classification: probability of maturity classes	Classification error: 0.51% to 17.77%	Kujawa et al. (2020)
Composting process control and optimization	ANN	412	Time, flow direction, density indicator, hydraulic load, flow (5 input parameters)	Pressure drop	Correlation coefficient: 0.906	Sidelko et al. (2019)
	ANN RBF-ANN GRNN	550	Chemical and physical parameters of composting (7 input parameters)	Ammonia emission	R: 0.972–0.981	Boniecki et al. (2012)
	ANN	52	Food and yard percentage, ash and scoria percentage, the moisture content, the fixed carbon content, the total amount of organic matter, high calorific value, and pH (7 input parameters)	C/N	Average relative error: 6.376%	Bayram et al. (2011)
	ANN	–	Time, turning frequency and mixing ratio (3 input parameters)	Response parameters: temperature, pH, O_2, respiration index, total organic carbon, TN, TP	RSME: range from 4.1 to 8.3%	Soto-Paz et al. (2020)
	ANN	20	pH, electrical conductivity, C/N, NH_4/NO_3 ratio, water soluble carbon, dehydrogenase enzyme, TP or TN (7 input parameters)	TN or TP value	R^2 (TN): 0.9983 R^2 (TP): 0.9991	Hosseinzadeh et al. (2020)

Table. 5.3 Summery of ML algorithms for MSW composting

5.2.1.7 Landfill :

Landfills are widely used waste disposal methods at home and abroad. Waste that cannot be recycled or incinerated is placed in landfills (Edgar et al., 2020). This method can handle large amounts of MSW, which is convenient and easy to operate. However, landfills occupy a large amount of land resources, and in the process of waste decomposition, various physical, chemical, and biological reactions occur in the landfill, resulting in serious pollution. As shown in Table 6, some studies have used ML algorithms to estimate landfill areas, predict landfill leachate generation, and monitor landfill gas (LFG). ANN and ANFIS are the most commonly used models. ML algorithms use influencing factors such as temperature and rainfall as input features to model the process of leachate and LFG production and obtain high accuracy (Abunama et al., 2019; Li et al., 2011). An accurate and reliable prediction is needed for proper design and operation and helps eliminate environmental impacts and maximize the use of resources.

Table 6. Summary of ML algorithms used in MSW landfill.

Application	Algorithms	Data size	Input feature	output	Error metrics	Reference
Landfill leachate prediction	ANN, SVM	120	Waste quantity, rainfall level, and emanated gases, etc. (9 or 3 input parameters)	Monthly leachate generation rate	R^2: 0.964 RMSE: 354.7 (ANN) R^2: 0.889 RSME: 692.1 (SVM)	Abunama et al. (2019)
	ANFIS	120	Waste quantity, rainfall level, and emanated gases (3 input parameters)	Monthly leachate generation rate	R: 0.952	Abunama et al. (2018)
	ANN	–	Meteorological parameters, measured parameters (11 input parameters)	Leachate daily flow-rate	R: 0.847 MSE: 0.0308	Karaca and Ozkaya (2006)
Landfill gas prediction	Auto-regressive neural network	1883	Mean air temperature, maximum pressure, minimum humidity, maximum wind speed, maximum humidity (5 input parameters)	Daily CH_4 generation rate	MAPE 3.03%	Fallah et al. (2020)
	ANN	121	Soil and air temperature, soil moisture content, CH_4 and O_2 concentration (5 input parameters)	CH_4 oxidation	R^2: 0.937 MSE: 0.0082	Abushammala et al. (2014)
	ANN	–	CO_2 content, meteorological parameters, etc. (12 input parameters)	Superficial gas flux	Error variance: 36	Scozzari (2008)
Landfill area estimation	ANN	180	Trip number of vehicles, month of the year (2 input parameters)	Waste quantity	R^2: 0.86	Hoque and Rahman (2020)
	ANFIS	–	Age groups of 0–14, 15–64 and 65+ (3 input parameters)	Waste generation rate	RMSE: 3.860 R^2: 0.99	Younes et al. (2016)
Landfill surface temperature	ANN	7830	Meteorological parameters (6 input parameters)	Landfill surface temperature	R: 0.884	Abu Qdais and Shatnawi (2019)

Table. 5.4 Summery of ML algorithms for MSW Landfill

Although ML algorithms have been widely used in MSWM, they are still at an early stage of development and use. There are some gaps in the application of ML algorithms to MSWM, and some aspects should be considered in the future.

5.2.1.8 ML algorithm selection :

There are currently a variety of ML algorithms, but there is no clear standard for which algorithm should be chosen. One solution is to try different algorithms on the same dataset to obtain the best model for the target case. According to existing literature, ANN is the most commonly used algorithm, whether as the main model or as a comparable one for evaluation, but ANN is prone to over fitting and is a black box. Again CNN has been widely used in MSW classification with high accuracy (Togacar et al., 2020).

5.3 Smart Waste classification methodology in the processing plant :

The methodology is a combination of two parts, namely, waste classification through convolutional neural network (CNN)and architectural design of smart trash boxes, which aids real-time data monitoring using Internat Of Things (IoT). Two structural models are merged to find excellent results in the field of waste management. Classifying wastes into proper categories helps to identify reusable waste. In the extent of image classification, deep learning algorithms acquire peerless results. The scope of minimizing the misuse of recyclable components inspires authors to add deep learning for waste classification while monitoring waste to differentiate recyclable wastes. The wastes is divided into two broad categories named digestible and indigestible. The waste classification using deep learning technology helps to attain categories of wastes from images. The architecture of trash boxes enables multiple sensors to take readings and data transmission for monitoring. Fig. 1 shows a block diagram of the system.

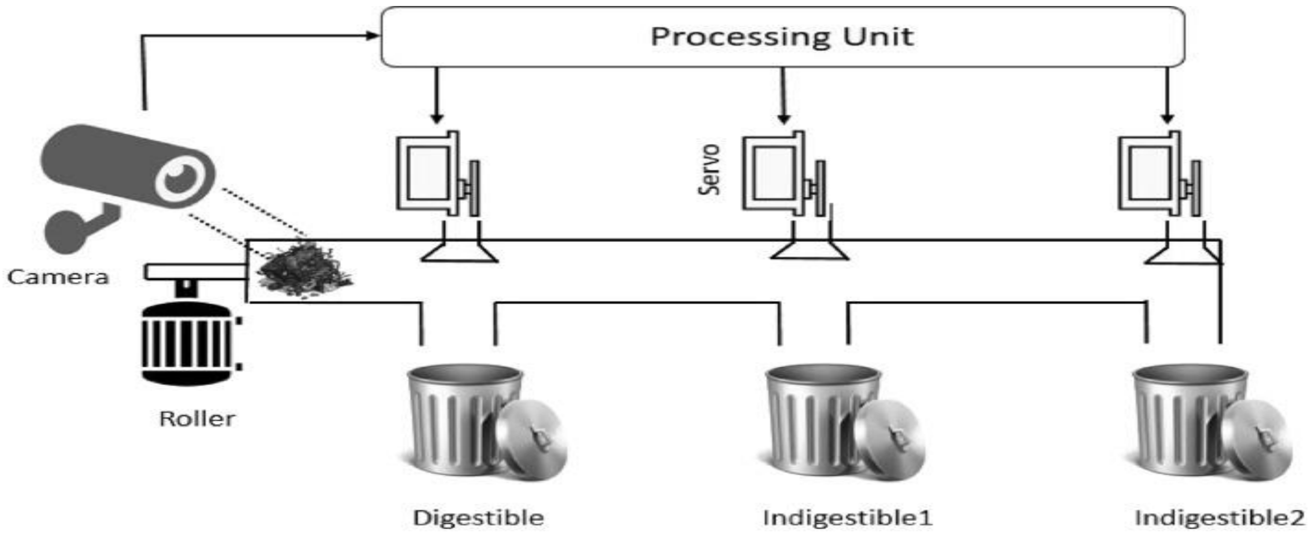


Figure 5.5 A block diagram of the proposed smart system

In this scheme, a camera module will scan the waste materials. After successfully finishing the waste scanning and image capturing process, a pre-processing component for the captured images taken by the camera in real-time is performed. The model utilizes the only image resizing due to ensure less complexity. After that, the pre-processed images are processed by a microprocessor (Raspberry pi). The microprocessor will classify the image using a classifier and sends a command to a servo motor to put waste into the corresponding trash box. This system also includes a roller which is capable of carrying the waste according to the instructions from the processing unit. Whenever the processing unit classifies waste, it sends a signal to the roller to carry that waste to the servo motor. Afterward, it stops rolling and waits for the next command from the processing unit

5.3.1 Working Principle of Camera Module and Servo Motor

The camera module is attached to the microcontroller of the proposed system and responsible for capturing images of wastes. Fig. 2 shows a flow chart diagram of a camera module. Primarily, the system will be initialized and prepared for image acquisition. The camera module captures an image and sends it to the microcontroller. After receiving the image, the microcontroller will feed the image to an already trained CNN model, and the model will make a response about that image. The microcontroller uses CNN response to instruct servo motor to put the waste into the respective trash box. The microcontroller takes the decision based on the probability of individual waste belong to digestible or indigestible. Then servo motor performs its job by taking the waste and put it into the respective trash box

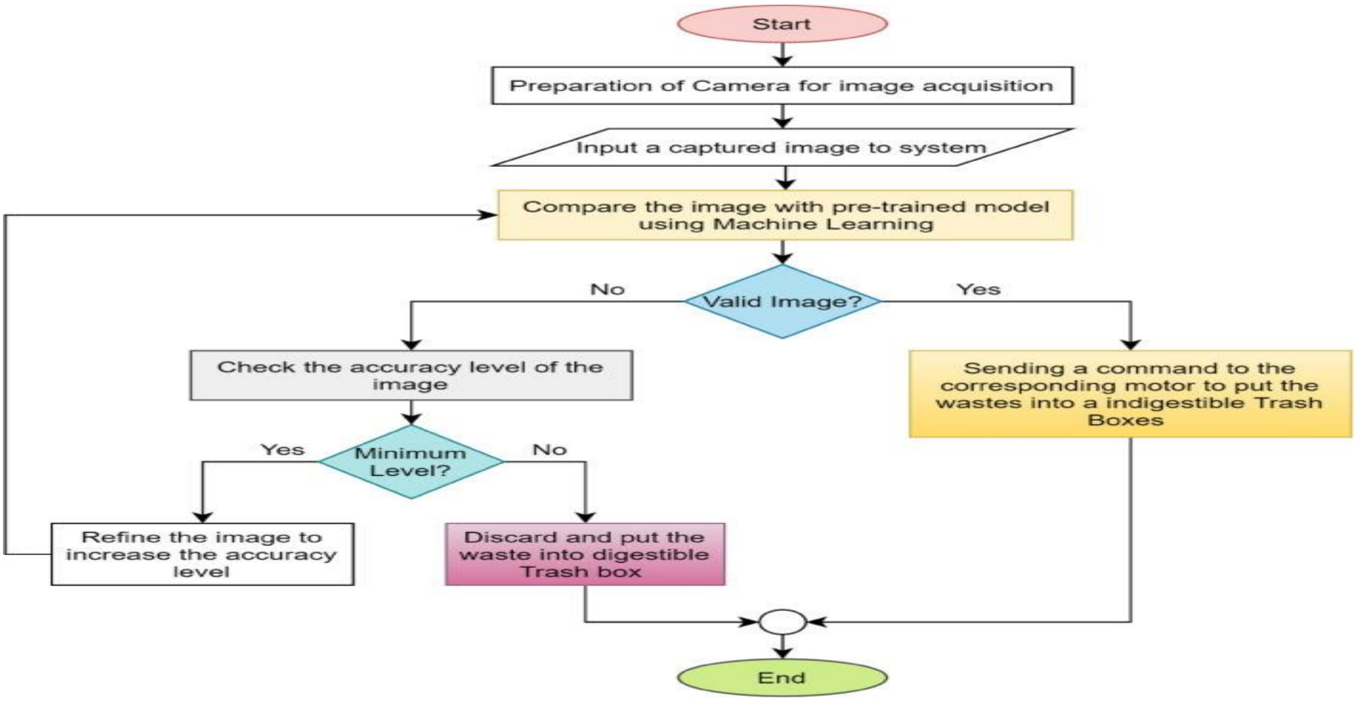


Figure 5.6 Camera module working principle

5.3.2 Implementation and Working Principle of Smart Waste Bin:

An ultrasonic sensor is attached to the microcontroller to measure the empty level of the trash box. The ultrasonic sensor is placed at the top of our developed model. Ultrasound is transmitted and received to calculate the empty level of the trash bin. The calculated value is sent to the microcontroller. A load measurement sensor is also placed at the bottom of the surface. This sensor is responsible for calculating the weight of the waste in Kg. The load measurement sensor works on the upcoming load of waste concerning time. When a load of waste in the trash box is increasing periodically, the value of load is also increased. Then the updated value is provided to the microcontroller. The values of the ultrasonic transducer and load measurement sensor are sent to the developed android application. The users can easily observe the weight of the trash and current empty layer of the bin using an android application. If the internet connection is available, the corresponding values will send to the cloud server, and the users will be able to monitor the data in real-time through an android app. Fig. 5.7 and 5.8 represents a flow chart of the working methodology of the ultrasonic sensor. In this figure, the system first initialized the ultrasonic sensor. The sensor sends and receives an ultrasound to measure the empty level of the trash box. Also, the ultrasound sensor sends the corresponding measured data to the microcontroller. To check the validity of an empty level, a threshold of the scale have been placed. If the waste crosses the threshold level, the system will stop the respective process and alert the user by sending a notification to clean and replace the trash box via an android application. In the case of an unavailable internet connection, no data will be sent.

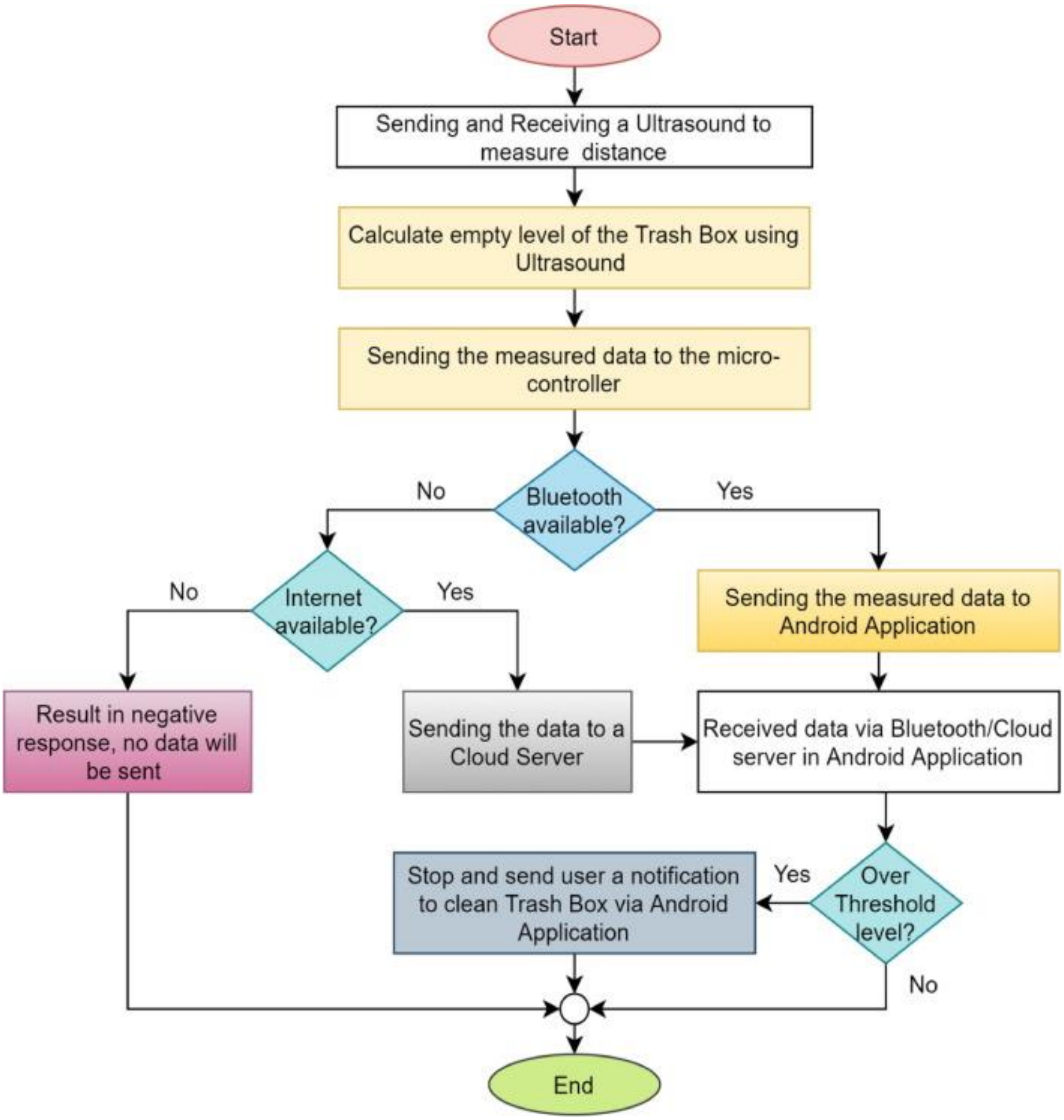


Figure 5.7 A flow chart of the ultrasonic sensor working principle(For measuring Waste level)

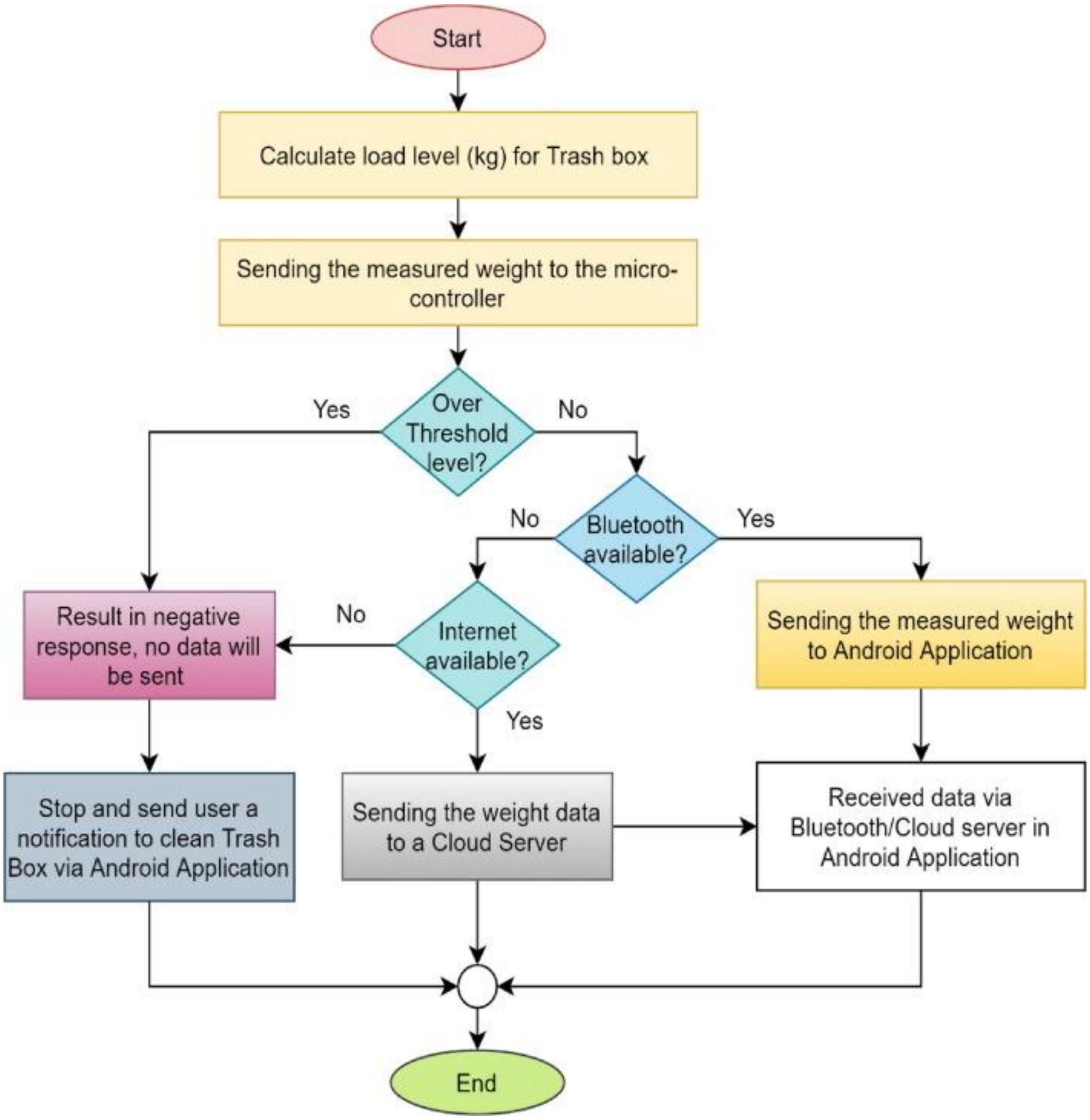


Figure 5.8 A flow chart of the ultrasonic sensor working principle(For measuring Load)

6.0 MODEL IMPLEMENTATION ON STUDY AREA DATA & RESULTS

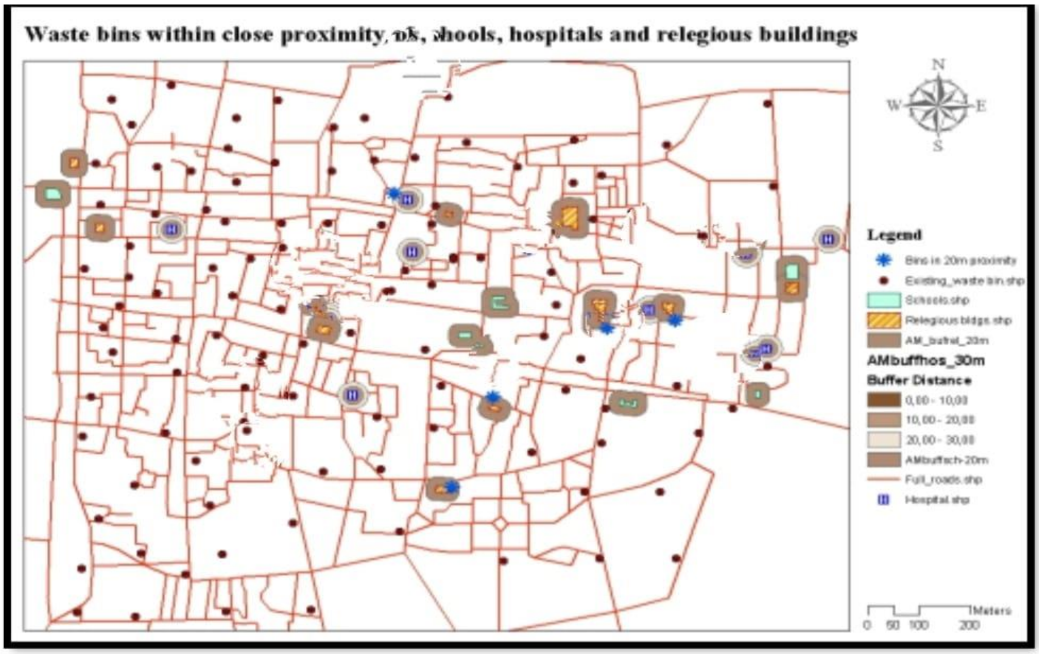
6.1 RESULTS AND DISCUSSION :

6.1.1 Application of Geographical Information System (GIS) :

This chapter is a discussion of the implementation of GIS workflow model on the case study area data and the results of the analysis. This model is implemented on the data using GIS software Arc View 3.3 and Arc Map. We have data of Thane, Mumbai and we will be implementing the proposed model on the case study area of 2 sq. km. The first analysis is for studying the inconvenience to schools, hospitals and religious buildings due to close proximity of the waste bins. For this, a buffer analysis of 20 meters is carried around these three land use buildings. Separate buffers are applied on each of the land uses i.e. schools, hospitals and religious buildings. The buffer of 30 meters around the hospital buildings point features is created in three bands of 10 meter each.

After application of the buffer the following results were obtained which can be seen in figure 6.1;

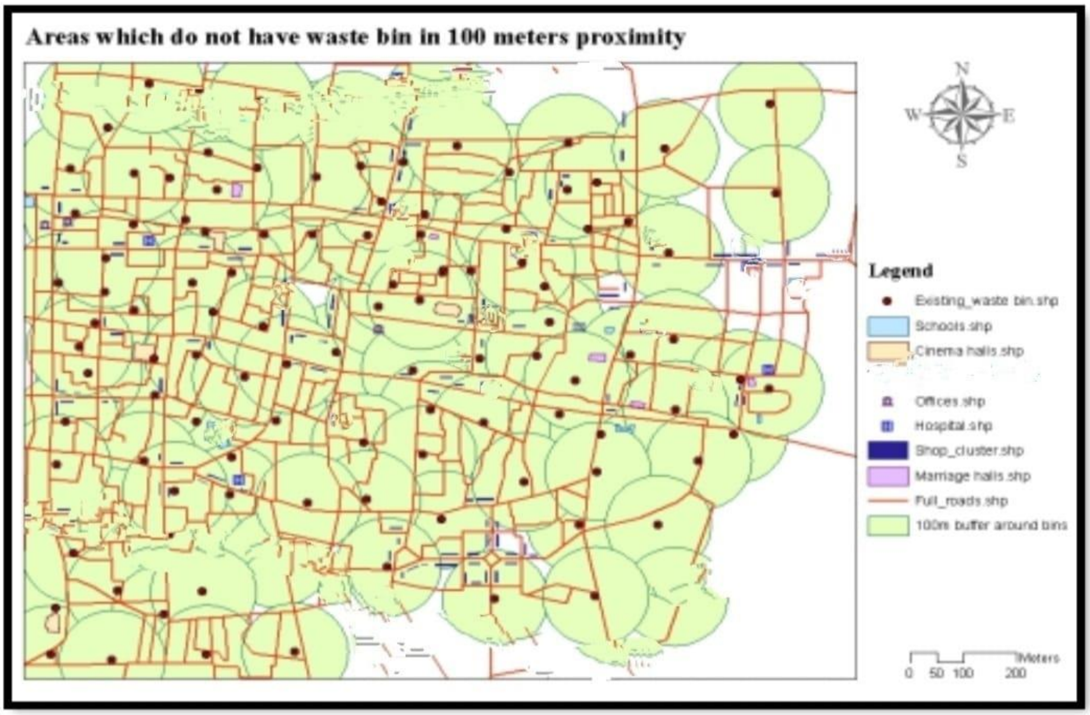
- There is only one municipal waste bins in a proximity of 20 meters of a school buildings.
- There are two municipal waste bins in proximity of 20 meters of hospital buildings.
- There are three municipal waste bins in proximity of 20 meters of religious buildings.



[Fig.6.1: Waste bins within close proximity of sensitive buildings]

In all there are six waste bins in the case study area which are in close proximity of schools, hospitals and religious buildings. These are required to be moved out of the buffer range of the respective buildings.

The second analysis is to check the waste bins proximity from the users to provide the bins at a convenient distance from all the users. For this a buffer of 100 meters is created around all the waste bin.



[Fig.6.2: Areas which do not have waste bin within a distance of 100 meters]

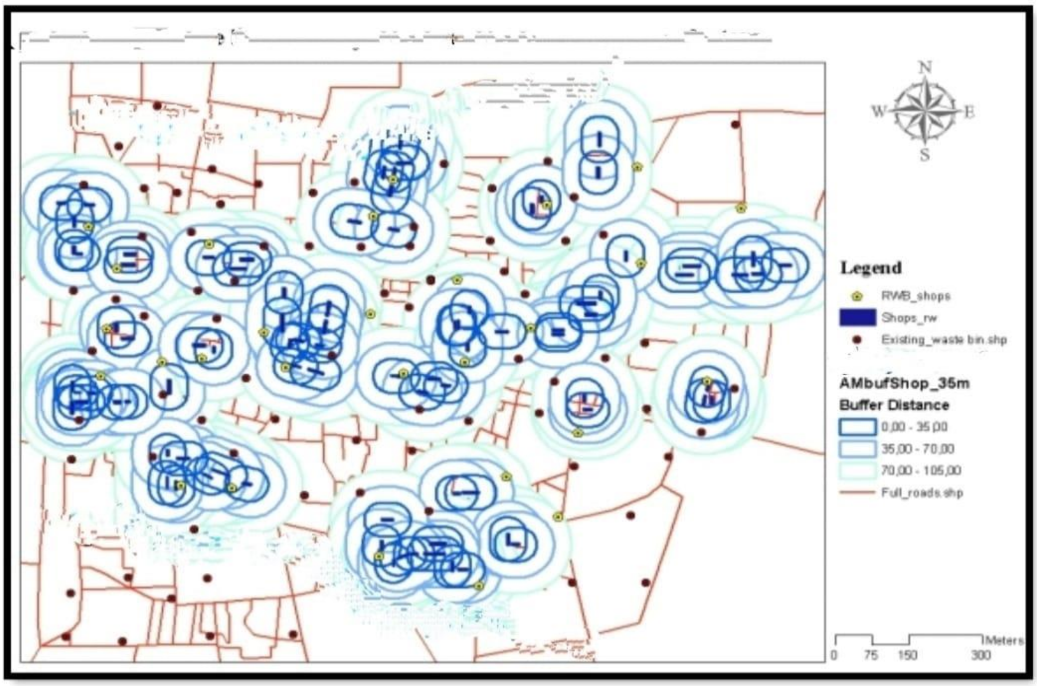
In the result of the analysis in figure 8.2 it is seen that most of the case study area is covered under the buffer except some areas. So the areas which do not come in the buffer range indicate that these areas do not have waste bins within a distance of 100 meters. So these areas require new waste bins within a distance of 100 meters. The allocation of bin can be done by finding a suitable location in the areas which needs waste bins. This will provide bins within a convenient distance range to all the residents. The proximity range can be again checked by applying buffer on the new bin locations.

Third analysis is for selecting the location for recyclable waste collection bins for recyclable waste generating land uses in order to provide recyclable waste bins along with existing waste bins for buildings which generate the recyclable waste. A buffer of 75 meters is applied around the school buildings, Malls with cinema theatres and marriage halls. The buffer is applied in three bands of 25 meters each. This would help to select the nearest located municipal waste bin for placing the new recyclable waste bin.

It was found that Malls with cinema theatres, marriage halls and office buildings all have waste bins in a range of 75 meters so recyclable waste collection bins can be placed with the nearest bin.

At some places one waste bin which was ideal location for placing a recyclable waste bin for a particular building as it was in its close proximity, but the same bin was also selected in the first analysis in the category of bins which were required to be moved away as they were too close to the same buildings. So that bin was ignored and the next nearest bin which do not come in the close proximity criteria constrain and also fulfil the buffer condition was considered suitable for allocating the recyclable waste collection bin for the same building.

The fourth analysis is to select locations for recyclable waste generating shops. The information about the recyclable waste generation group of shops needs to be identified from the total groups of shops available in the data. This information was extracted by applying a QUERY to the GIS data base already fed to the system. In the query results the group of shops generating both 'Recyclable' and 'Mixed' type of waste are selected. Now to find suitable location for placing the waste bins is carried by applying buffer on the shop clusters. Buffers are applied in three bands of 35 meters each. The bands will help to select the nearest located waste bin and also to select a bin which would be nearer for maximum possible group of shops. The results of this analysis can be seen in figure 8.6.



[Fig.6.3 : Allocation of waste bins for recyclable waste generating shops]

Now combining both of the above mentioned 'Third' and 'Fourth' analysis it was found that there are 37 bins to be provided beside the municipal waste bins for collection of recyclable waste.

6.1.2 Application of Artificial Intelligence (AI) :

Here as a better option we propose to provide with SMART WASTE BINS instead of providing two bins at the same location, i.e. One recyclable waste bin along with One existing Municipal waste bin.

Smart bins are part of an intelligent waste management system. They have wireless ultrasonic fill-level sensors embedded inside which detect how full the bin is and then, through the IoT, this data is sent to a cloud-based monitoring and analytics platform. On the basis of this data, waste collection services can optimise their routes and frequency.

Sorting needs to be done once the waste has been collected. This sorting is generally performed at the **waste management facility** where AI-powered robots can efficiently sort the items. Essentially, AI speeds up the process as human labour can sort 30 to 40 items per minute while the same number reaches 160 if done with AI-powered machines. Once the garbage is on the conveyor belt, products are scanned with cameras followed by analysis from deep learning algorithms. Robots and relevant apparatus can then pull off the segregated items from the belt for further processing.

For selecting the location of the smart bins in the case study area we carried out a **simulation procedure** by placing real smart intelligent bins in the selected areas as per our 'Third' and 'Fourth' analysis as above . After this, a convenient location of the **waste management facility** along with the optimum route of transporting the collected waste material from the bins was selected . For this we adopted a trial and error method with the help of GPS technology . In this waste management facility recyclable materials will be sorted out for further processing into five categories, namely cardboard, glass, metal, paper, and plastic, with the help of AI and ML system using different algorithms with much accuracy and the Waste that cannot be recycled will be placed in landfills. An illustration of these location have been indicated in the figure below :

[Fig.6.4: Positions of Smart waste bins for the case study area with waste management facility]

6.2 CONCLUSION AND FUTURE SCOPE :

The model proposed in this paper was designed for planning the allocation of waste bins in the case study area. There were several aspects taken into consideration in planning the waste management by evaluating the bin allocation. First was to analyse the location of the existing waste bins in the area. The planning concern was to verify the convenience and inconvenience of the users from the existing bin location. This was done by checking the location of bins for a convenient proximity distance for all the users and also for the inconvenience to the users due to close proximity of the bins to sensitive land uses. Here as a better option we propose to provide with SMART WASTE BINS instead of providing two bins at the same location, i.e. One recyclable waste bin along with One existing Municipal waste bin.

Using the Internet of Things, this study illustrates how smart waste management may be done. This method ensures that waste is collected as soon as it reaches the maximum level. As a result, the system will provide accurate reports, therefore boosting its efficiency. The authors intend to evolve a smart waste management system based on the perception of sustainable, integrated waste management. The closure of landfills could pose various potential hazards due to which public health may get affected. Open junkyards and the burning of undesirable wastes can lead to environmental pollution and many hazardous diseases. There should be a system that can effectively supervise the disposal and collection of waste and regulate the comprehensive growth of superfluous waste. The system proposed by us collects and efficiently treats the waste as compared to other models. It also saves fuel costs as well as time. The system is also tracking the garbage collecting trucks, which provides real-time trucks' real-time positions, thereby increasing work efficiency. All the previous waste management models mainly focus on increasing sustainability and ignoring the overall system's time and cost. However, our waste management technique is sustainable and reduces the time and cost of the setup. With the help of image processing, the system predicted the waste index of a particular dumping ground. According to the priority, the waste-collecting vans will collect waste, which saves much time. With respect to the infrastructure in India, the model proposed in this paper is designed to integrate the different stakeholders of the waste management system, such as smart bins and sensors at the source area and vehicles. The system is efficient and effective because smart bins, collection vehicles, and routes are dynamically updated.

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