MANAGEMENT AND PLANNING FOR DISPOSAL OF SOLID WASTE: A CASE STUDY

Submitted in partial fulfilment of the requirements

for the degree of

MASTER OF ENGINEERING

in

CIVIL ENGINEERING

(With specialization in Construction Engineering and Management)

by

Nalband Irfan Innus

(Registration No. Anjuman 17)

Under the guidance of

Dr. R. B. MAGAR

Department of Civil Engineering,

Anjuman-I-Islam's Kalsekar Technical Campus,

Sector- 16, Khandagaon, New Panvel- 410206

University of Mumbai

(2015-2016)

A Dissertation Report on

MANAGEMENT AND PLANNING FOR DISPOSAL OF SOLID WASTE: A CASE STUDY

Submitted in partial fulfilment of the requirements

for the degree of

MASTER OF ENGINEERING

in

CIVIL ENGINEERING

(With specialization in Construction Engineering and Management)

by

Nalband Irfan Innus

(Registration No. Anjuman 17)

Under the guidance of

Dr. R. B. MAGAR

Department of Civil Engineering,
Anjuman-I-Islam's Kalsekar Technical Campus,
Sector- 16, Khandagaon, New Panvel- 410206
University of Mumbai
(2015-2016)

CERTIFICATE

This is to certify that the project entitled **"Management and Planning for Disposal of Solid Waste: A Case Study"** is a bonafide work of **Nalband Irfan Innus (Registration No. Anjuman 17)** submitted to the University of Mumbai in partial fulfilment of the requirement for the award of the degree of "Master of Engineering" in "Civil Engineering (With Specialization in Construction Engineering and Management)"

Dr. R. B. Magar
(Guide and Head of Department)

Dr. Abdul Razak Honnutagi
(Director, AIKTC)

APPROVAL SHEET

This dissertation report entitled “Management and Planning for Disposal of Solid Waste: A Case Study” by Nalband Irfan Innus (Registration No. Anjuman 17) is approved for the degree of “Civil Engineering with Specialization in Construction Engineering and Management”

Examiners
1. …………………………
2. …………………………

Supervisors:
1. …………………………
2. …………………………

Date:
Place: Panvel

DECLARATION

I declare that this written submission represents my ideas in our own words and where others ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in our submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

Nalband Irfan Innus

(Reg. No. Anjuman 17)

Date:

ABSTRACT

Solid waste is generated from the society due to human activity which is unwanted, discarded and useless materials in the solid form. Management is a technique, principle and method for executing the work of effective disposal of solid waste whereas planning is the primary function of management which decides the future course of action in advance like rate of solid waste generation, methods of disposal and optimized route of transportation. Planning involves the steps like making forecast for achieving the goal, defining objectives, identifying the alternative course of action to achieve the goal. In this study an attempt has been made for proper management and planning for disposal of solid waste. The study area is selected from Panvel city, Maharashtra, India. Among the various types of wastes only MSW from the Panvel city is selected. In this work, an eco-friendly method of disposal is achieved by proper planning and management for municipal solid waste (MSW). Reducing, recycling and reusing is called as "3R" rule of solid waste and an attempt has been done to achieve this "3R" rule of solid waste. The total quantity of landfilling waste is successfully reduced, so the area required for landfill is also reduced which ultimately helps in saving land and respective economy. This also helps to prevent the land pollution as well it doesn't cause any harm to environment and the public health. CIDCO is planning for 5.5 Hector land for landfill up to the duration of 15.5 years (from year 2017 onwards) but in this work it is successfully planned for 4.54 Hector land up to the duration of 25 years (from year 2017 onwards) which saves the wastage of land. In this work, the population of Panvel area for next 3 decades (in year 2041) is predicted. This population forecasting is about 1721730 people after 3 decades (in year 2041). Existing method for disposal of solid waste is landfilling and then covering the waste from top which is very traditional method. CIDCO has been proposed the quantity of landfilling waste 365000 MT/year up to the duration of 15.5 years (from year 2017 onwards) but in this work the quantity of landfilling waste is successfully reduced up to 230000 MT/year for the duration of 25 years (from year 2017 onwards). The suggested method in this work for disposal MSW is segregation and then composting, incineration and landfilling as per characteristic of waste. This helps to save land pollution and wastage of land. An optimum route has been selected which saves distance and time of transportation as well as ultimately leads to save the cost of transportation of municipal solid waste (MSW) these things have been achieved in this work for study selected from Panvel city.

Keywords: municipal solid waste, eco-friendly disposal, optimum route, landfilling.

CONTENTS

Certificate	**i**
Approval Sheet	**ii**
Declaration	**iii**
Abstract	**iv**
Contents	**v**
List of Figures	**vii**
List of Tables	**viii**
Abbreviation Notation and Nomenclature	**ix**
Chapter 1 Introduction	**1**
1.1 General	1
1.2 Management of Waste	2
1.3 Processing of Waste	2
1.4 Disposal of Waste	2
1.5 Present scenario of MSW in Mumbai	3
1.6 Statement of the Problem	5
1.7 Objectives of the Study	6
1.8 Scope of proposed work	6
1.9 Organization of Dissertation	6
Chapter 2 Review of Literature	**8**
2.1 General	8
2.2 Overview of literature	8
2.3 Summary	16
Chapter 3 Methodology	**17**
3.1 General	17
3.2 Methods of population forecasting	19
3.2.1 Arithmetical increase method	19
3.2.2 Geometrical increase method	19
3.2.3 Incremental increase method	20
3.2.4 Graphical method	20
3.3 Route optimization	20
3.4 Assignment method	21

3.5 Summary	21
Chapter 4 Study Area and Data Collection	**22**
4.1 General	22
4.2 Statistical record of study area (Panvel)	22
4.3 Details of Taloja dumping ground	25
4.4 Summary	26
Chapter 5 Results and Discussions	**27**
5.1 General	27
5.2 Population forecasting	27
5.2.1 Graphical method	28
5.3 Calculation of Landfilling:	29
5.4 Calculation of Composting Area	33
5.5 Calculation of Incineration Area	36
5.6 Route Optimization:	37
5.7 Application of Primavera	38
5.8 Report generated through Primavera	39
5.9 Assignment of proper disposal method for MSW	41
5.10 Comparison between designed plant and CIDCO plant	43
5.11 Summary	43
Chapter 6 Summary and Conclusions	**45**
6.1 Summary	45
6.2 Conclusion	45
6.3 Future scope of work	46
References	**47**
List of Publications	**49**
Acknowledgement	**50**

LIST OF FIGURES

Figure 1.1 Deonar dumping ground	3
Figure 3.1 Flow chart of methodology adopted to achieve the objectives	18
Figure 4.1 Map of Panvel area	24
Figure 5.1 Graphical method	28
Figure 5.2 Dynamic Programming for route optimization	37
Figure 5.3 Optimum Route selection	38
Figure 5.4 Dynamic Programming for route optimization using PRIMAVERA software	39
Figure 5.5 Optimum Route selection using PRIMAVERA software	40
Figure 5.6 Gantt chart, Primavera software analysis report	40

LIST OF TABLES

Table 3.1 Last six decades population data 18

Table 4.1 Last six decades population data, Panvel 23

Table 4.2 Status of Solid Waste Disposal in Municipal Corporations of Maharashtra 23

Table 4.3 Quantity of solid waste disposed in all Municipal councils 23

Table 4.4 Municipal solid waste (MSW) analysis report 25

Table 4.5 Salient features of Taloja dumping ground 25

Table 5.1 Arithmetical increase, Geometrical increase and Incremental increase method 28

Table 5.2 Area of Panvel and population of the area in year 2041. 29

Table 5.3 Quantity of solid waste and facility of landfilling 30

Table 5.4 Landfill Waste in Percentage (%) 30

Table 5.5 Calculation of landfilling for 25 years up to 2041 32

Table 5.6 Composting Waste in Percentage (%) 33

Table 5.7 Calculation of composting area for 25 years 35

Table 5.8 Calculation of incineration area for 25 years 36

Table 5.9 Assignment of disposal methods to (Municipal Solid Waste) MSW 41

Table 5.10 Assignment of disposal methods to (Municipal Solid Waste) MSW 42

Table 5.11 Assignment of disposal methods to (Municipal Solid Waste) MSW 42

Table 5.12 MSW (Municipal Solid Waste) assigned to disposal methods 42

Table 5.13 Comparative statement 43

ABBREVIATION NOTATION AND NOMENCLATURE

MCGM	Municipal Corporation of Greater Mumbai
PMC	Panvel Municipal Corporation
MSW	Municipal solid wastes
SWM	Solid waste management
RDF	Refuse derived fuel
BMC	Brihnmumbai Municipal Corporation
MoUD	Ministry of Urban Development
LFG	Land filling gases
BARC	Bhabha Atomic Research Centre
ULBs	Urban Local Bodies
MPCB	Maharashtra Pollution Control Board
MT/D	Metric ton per day
COD	Chemical Oxygen Demand
C/N	Carbon / Nitrogen
MSWM	Municipal solid wastes Management
ISWM	Integrated Solid Waste Management
RCC	Reinforced Cement Concrete
GWT	Ground water table
CIDCO	City and Industrial Development Corporation
MT	Metric ton
AIM	Arithmetical increase method
GIM	Geometrical increase method
IIM	Incremental increase method

Chapter 1

Introduction

1.1 General

India is developing country, where cities are growing at faster rate, generation of solid waste is also increasing with rising population and huge number of heaps of garbage are found all over city which causes nuisance to environment and human health. Huge volume of solid waste is daily generated in metropolitan cities and management of solid waste is a major challenge. A number of processes are involved in the effectively managing waste for a municipality. These include monitoring, collection, transport, processing, recycling and disposal. But leachate produced from decaying garbage mixes with the local water bodies causes contamination of water or causes nuisance, breeding of flies, mosquitoes, insects which causes diseases to people. Municipal Corporation of Greater Mumbai (MCGM) and Panvel Municipal Corporation (PMC) are adopting different methods for the disposal of solid waste generated by societies and also investing huge amount for cleaning of cities but still the problem of solid waste disposal is not completely solved due to improper management of solid waste collection, transportation, storage and disposal as well as due to poor planning of solid waste management. (Joshi, 2013)

1.2 Management of Waste

The Municipal Corporation of Greater Mumbai (MCGM) is formally responsible for the management of waste in the city. The prevailing approach has been one of collection and disposal that is, garbage is collected from communities by the municipal authorities and disposed of at the three main dumping sites that are currently servicing the city Garbage collectors employed by various housing societies manually collect the waste generated at the household level and dump it in the garbage bin at specified street corners. There are around 5,800 community bins in the city. In case of South Mumbai, trucks collect garbage from the garbage bins and transport it to a transfer station which is located in Mahalakshmi. A separate transport is arranged for transferring the garbage from Mahalakshmi to the northern part of Mumbai where the dumping grounds are situated. From all other parts of the city, garbage is sent directly to the dumping grounds. Nearly 95% of the waste generated in the city is disposed of in this manner. (Mukherjee, 2015)

1.3 Processing of Waste

Generally, no processing of municipal solid waste is done in the country. Only a few cities have been practising decentralized or centralized composting on a limited scale using aerobic or anaerobic systems of composting. In some towns un-segregated waste is put into the pits and allowed to decay for more than six months and the semi-decomposed material is sold out as compost. In some large cities aerobic compost plants of 100 MT to 700 MT capacities are set up but they are functioning much below installed capacity. A few towns are practising vermi-composting on a limited scale. (Rana, 2014)

1.4 Disposal of Waste

Disposal of waste is the most neglected area of SWM services and the current practices are grossly unscientific. Almost all municipal authorities deposit solid waste at a dump-yard situated within or outside the city haphazardly and do not bother to spread and cover the waste with inert material. These sites emanate foul smell and become breeding grounds for flies, rodent, and pests. Liquid seeping through the rotting organic waste called leachate pollutes underground water and poses a serious threat to health and environment. Landfill sites also release landfill gas with 50 to 60 per cent methane by volume. Methane is 21 times more potent than carbon dioxide aggravating problems related to global warming. It is estimated by TERI that in 1997 India released about 7 million tonnes of methane into the atmosphere. This could increase to 39 million tonnes by 2047 if no efforts are made to reduce the emission through composting, recycling, etc. (Rout and Sharma, 2010). The main technological options available for processing/ treatment and disposal of MSW are composting, vermicomposting, anaerobic digestion/bio methanation, incineration, gasification and pyrolysis, plasma pyrolysis, production of Refuse Derived Fuel (RDF), also known as palletisation and sanitary landfilling/landfill gas recovery. Not all technologies are equally good. Each one of them has advantages and limitations. (Asnani, 2004)

1.5 Present scenario of MSW in Mumbai

In 2011-12, Mumbai alone accounted for 6.11% of the total waste generated daily in India. As its waste piles, up, the land-starved city is staring at the big question. Environmentalists believe the BMC's current policies are in violation of MSW Rules, 2000, as the corporation allows compactor trucks to collect mixed waste and fails to penalize buildings that do not segregate waste. In February last year, a circular issued by deputy municipal commissioner (SWM) Prakash Patil stated that by July 2013, the corporation would stop accepting mixed waste and issue legal notices to housing societies that fail to segregate waste at the source. (Indian Express, 6 Feb 2014) Fig 1.1 shows scattered and mismanaged solid waste at Deonar dumping ground. Due to improper arrangements, it's becoming waste hump at site and creating nuisance in surrounding.

(*Source: httpwww.mid-day. comarticlesmumbai-has-no-space-to-dump-its garbage15898155*)

Figure 1.1 Deonar dumping ground

Deonar dumping ground facing excess waste dumping against its capacity, which is resulting in scattering of solid waste at dumping ground and nearby areas.

The plan has yet to be finalized. “Segregation was widely successful between 1997 and 2004, where the civic body roped to encourage composting in an effort to decentralize waste management. But the current policy, of awarding centralized contracts to private companies running compactor trucks and paying a tipping fee to private contractor (the case in Kanjurmarg) for every tons of waste accepted at the dump yard, reverses the previous successful policies,” Rishi Aggarwal, a research fellow with Observer Research Foundation, says adding that the civic body has failed to make residents a partner in solid waste management, but has put its faith in private parties to manage waste. Questions have been repeatedly raised over the quality of service provided by the contractors in collection and transportation of waste. Critics say while the BMC has an elaborate system in place for collection and transportation of waste, there are no real-time checks in place to see if the appointed contractors are following specifications. In a major health hazard, conservancy workers involved in collection, transportation and disposal continue to work without wearing the prescribed rubber gloves, face masks, reflector jackets and safety shoes. (Indian Express, 6 Feb 2014). Instead of assigning officers to inspect the work, it will be monitored from the offices through live feeds,” says Patil. The initiative is part of the civic body’s attempt to comply with standards set by the Ministry of Urban Development’s (MoUD) for urban local bodies to enhance the quality of civic amenities. Apart from effective garbage collection, the civic body will also have to ensure 80 per cent recovery of collected waste through recycling, 100 per cent scientific disposal of municipal solid waste, 100 per cent cost recovery in SWM services and 90 per cent efficiency in collection of SWM charges. Starting with collection, Dr Sahu says “If BMC wants to increase segregation of waste, it will first have to invest in more dust bins for Mumbai. Different dust bins for different types of waste should be provided so that residents are publicly educated to segregate wet waste from paper, plastic, glass and metal. (Indian Express, 6 Feb 2014)

After the fire accident at Deonar dumping ground BMC has undertaken a slew of measures to tackle fire incidents. About seven acres have been covered with mud, five bore wells have been dug for easy access to water in case of fires, and hollow pipe drains to release accumulated methane. Civic medical officers surveyed the affected area surrounding Deonar and screened 1.7 lakh families for smoke-related problems. About 72 % people had respiratory problems. (Indian Express, 6 April 2016)

The Brihanmumbai Municipal Corporation (BMC) has still not done anything to segregate or recycle its plastic waste. A citizens' group complained that all the waste is ending up either at landfills or in the sea. The group, Watchdog Foundation, which studied the waste dumped at the Deonar, Mulund and Kanjurmarg landfills, filed a complaint with the BMC on Wednesday saying that Mumbai did not have a single plastic waste management facility. In March 2016, the Centre came up with the Plastic Waste Management Rules, 2016, to bring down plastic waste. According to the Union environment ministry, India generates 16,000 metric tons (MT) of plastic was daily. Of this, 10,000 MT is collected and processed, and the rest ends up in dumps and drains that empty into the sea. BMC estimates that of the 8,000-8,300 MT tons of garbage generated by Mumbai, 750 MT is plastic. (Hindustan Times, 25 May 2017)

The BMC allocated Rs 2,280 crores as part of its budget for solid waste management this year, which also happens to be the highest budgetary allocation as opposed to previous years. BMC officials said according to the new rules, plastic is being segregated at 32 waste segregation centers in the city, along with wet and dry waste and an additional 32 centers will be active by the end of this year. "While there are no plastic manufacturing units in Mumbai, there are many in the outskirts. So, a lot of plastic, mostly below 50 microns, is brought into the city undetected," said a senior official from BMC's solid waste management department. "The new rules clearly establish that plastic needs to be segregated at the source, which is not happening. Thus, there is more need for awareness at the household level to segregate waste into three categories – dry, waste and plastic." (Hindustan Times, 25 May 2017)

1.6 Statement of the Problem

Maximum area of land is undergoing for landfilling which is very uneconomical and unnecessarily wastage of land. This problem is getting more critical day by day with increase in population and rate of generation of solid waste with respect to population. Hence in this work as a case study small area of Panvel is selected and collected relative data like rate of solid waste generation per day, adopted method of disposal, population of last six decades, etc. from Panvel Municipal Corporation (PMC) office, it's observed that there is also failure of management and planning for disposal of municipal solid waste (MSW) generated by Panvel population and this problem leads to harm environment and society. So, management tools like route optimization and assignment of proper disposal methods are need to use for improvement of solid waste management scenario in Panvel region.

1.7 Objectives of the Study

The experimental work is carried out to optimize the land acquired for landfilling and method for disposal of solid waste. A case study of Panvel area is taken to propose solid waste management system and optimizing the time and ultimately cost without harming the public health, environment and ecosystem. Pursuant to this, following objectives are proposed in the present investigation.

1. To forecast the data on the basis of available data of previous decades and the rate of generation of solid waste.
2. To study the existing methods of disposal of solid waste.
3. To suggest the waste disposal method with route, time, cost optimization without causing harm to society.

1.8 Scope of proposed work

The scope of the proposed work is to plan and manage proper system of solid waste disposal with route, time, cost optimization and principle of 4Rs (Reduce, Reuse, Recycle, Recover) without causing any harm to public health, environment, ecosystem. Attempts of proper management, saving cost and least acquisition of land are achieved.

1.9 Organization of Dissertation

This dissertation report comprises of following chapters. The brief contents have been discussed as below:

Chapter One contains the background to the study, objective of the work, scope of the work & organization of the dissertation.

Chapter Two contains overall review of literature on management of municipal solid waste and present scenario of solid waste management for various cities.

Chapter Three deals with study area and data collections for this work and about visit to Taloja dumping ground where MSW of Panvel is dumped.

Chapter Four deals with method and methodology adopted for this work and rate of solid waste generation by current population and population after 3 decades.

Chapter Five deals with the results and discussions as well as summary.

Chapter Six deals with PRIMAVERA software report summary.

Chapter Seven deals with the conclusions, future scope and summary

Chapter 2

Review of Literature

2.1 General

Many researchers and municipal waste management corporations attempt for the best from waste; here we discuss some of works based on management, planning, recycling and disposal of municipal solid waste (MSW); here we discuss some of works-based collection, transport, disposal of solid waste.

2.2 Overview of literature

Vaidya (2002) studied that bioreactor landfills offer a sustainable way to achieve increased waste degradation along with benefits such as enhanced landfill gas (LFG) recovery, reduction in leachate pollution potential and rapid increase in landfill volumetric capacity. It also offers significant reduction in post closure management activities as leachate treatment, LFG impact on the environment and improves the potential for land reuse. Methodologies to improve the degradation rate and process are refuse shredding, nutrient addition, pH buffering, and temperature control along with moisture enhancement. Here the main attention was given on landfill gases and reduction in leachate pollution.

Asnani (2004) reported levels of SWM services in the country have started improving on account of active monitoring by the Supreme Court of India, the central and state pollution control boards and finance and technical support from proactive state governments there still is a long way to go. Save the formalization of the MSW Rules 2000, state action in this regard at many levels has been fairly uninspiring thus far. While MSW Rules 2000 is a watershed document in India's history of effective SWM, implementation issues still overwhelm the system. A firm commitment from central and the state governments towards a time bound mission to turn the provisions into action is urgent. Here it is said that management of solid waste can hardly be cited as instances of governmental awareness and sensitivity to a problem that is only getting more daunting with each passing hour.

Shah (2006) concluded that serious problems relating to waste disposal methods in major metropolitan cities will remain as it is if immediate action is not taken by concerned authorities. Waste dumping activity by Municipal authorities in Mumbai is certainly a cause of concern for city dwellers. Dumping approach has many direct and indirect hazards for human, environment and for eco system. Waste segregation at the source will be another major issue which needs proper attention. Without waste segregation at source, solid waste processing projects for any operator will not be economical. BARC's Nisargruna technology for processing solid waste is indigenous technology. A Nisargruna plant observation at Govandi, Mumbai proves that plant is successfully processing solid waste and technology is beneficial in many ways. Biogas production is faster because of combination of aerobic and anaerobic digestion technology. This technology development will save environment to greater extent. Entrepreneurs will excel in their ventures by selling services and products related to Nisargruna Technology. Shree Mukti Sangathan is operating some Nisargruna Plants, thus enabling employment to the poor waste pickers. Here it is explained that comparison with other waste processing technologies, Nisargruna seems to be sustainable in all aspects including social and business aspects.

Varma (2007) studied that in the major cities of the State, around 80% of the waste is compostable organics enabling high level of recycling in the form of manure or fuel and high moisture content, low calorific value and high nutrient content making the dominant organic fraction of waste more conducive for recycling in the form of manure. Generally, data on the quantity of MSW generation is maintained by the Urban Local Bodies (ULBs). This is generated based on the quantity of waste collected and transported on a day to day basis, based on the number of trips made or on approximation based on guesstimates. Here the main attention is given on recycling of MSW which is eco-friendly and helpful to generate revenue also.

Shirke (2009) reported that as per the Maharashtra Pollution Control Board (MPCB) report, total solid waste generated in 22 Municipal Corporations is 13889 MT/D and solid waste generated in 231 Municipal Councils is 2727.29 MT/D. So, one can imagine the difficult task of collecting the generated municipal solid waste. As the major part of this MSW is a one-point source, collecting it becomes difficult. According to the State of Environment Report, 2009 about 90 percent of the municipal solid waste generated in Mumbai and Chennai was collected. However, in Delhi, there is no efficient system of collection as only 77 percent of the municipal solid waste generated was collected. Solid wastes are those organic and inorganic waste materials produced by various activities of the society, which have lost their value to the first user. Improper disposal of solid wastes pollutes all the vital components of the living environment (i.e., air, land and water) at local and global levels. The problem is more acute in developing nations than in developed nations, as their economic growth as well as urbanization is more rapid. There has been a significant increase in MSW (municipal solid waste) generation in India in the last few decades. This is largely because of rapid population growth and economic development in the country. Here it is said that due to rapid growth of urban population, as well as constraint in resources, the management of solid waste poses a difficult and complex problem for the society and its improper management gravely affects the public health and degrades environment

Gautam et al. (2010) presented that municipal solid waste is suitable for composting because of the presence of high percentage of biodegradable organic matter, acceptable moisture content and C/N ration in the waste. However, the composting process and compost quality could further be improved by adding inoculating agent like cow manure, poultry manure, yard waste etc. in the municipal solid waste. Since Jabalpur soil is sandy, erodible, low water holding capacity with little organic matter and nutrient content, the application of compost would be an investment in the long term for the health of soils and plants. Here it is concluded that a module of this type for the recovery of valuable and economical organic fertilizer- the compost, can be adapted country wide to recycle the organic residues as waste management option.

Rout et al. (2010) explained that the amount of food waste was the highest in general MSW. Soil has the lowest percentage in MSW. It shows that most of the waste dumped at solid waste dumping site consists of kitchen waste. The study was carried out by using two bioreactors containing approximately 10 kg of waste each, in order to follow waste degradation over 16 weeks of time period. The main difference between anaerobic recirculated and without recirculation bioreactors options is determined in leachate quality. Leachate quality is regularly measured by the means of pH, electrical conductivity, calcium, magnesium, total nitrogen, phosphate and chemical oxygen demand (COD). It has been observed that leachate recirculation is more effective on anaerobic degradation of solid waste than non-recirculated degradation. The leachate recirculated bioreactor appears to be the more effective option in the removal of COD by 89.93% and stabilisation of pH at 7.5. After 16 weeks of anaerobic degradation, waste stabilization seemed to have reached for the recirculated bioreactor.

Das (2013) explained that the present disposal method, open dumping, must be immediately abandoned. The present sorting process is not effective. Ideally, all of the valuable materials should be collected separately at the source and transported to the recycling/recovery centre in order to increase the economic benefit. Educational programs, which will be hopeful to decrease the waste loads for solid waste collection, separation and recycling may be conducted. The municipal corporation certain modifications and improvements to solid waste management services have been done, this is still not sufficient to mitigate the present and future problems of solid waste management in Kolkata. To achieve a target of 100% collection, transportation, treatment, and disposal, Municipal Corporation would first need to prepare a macro plan which would identify the quantity of waste generated in the municipality and the broad strategy to be adopted to manage the system. This should be followed by a micro or locality-based plan, which would provide details as to routes, timing, equipment, and manpower deployment.

Francis (2013) concluded that the segregation of waste at source and promotion of recycling or reuse of segregated materials reduces the quantity of waste and the burden on landfills and provides raw materials for manufacturers. The composition of MSW shows mostly organic matter (45.3%), so composting is a good method for the treatment and production of soil amendment. The rapid increase in the quantities of MSW and the inability to provide daily collection service cause a nuisance and health hazards. The segregation of waste at source and promotion of recycling or reuse of segregated materials reduces the quantity of waste and the burden on landfills and provides raw materials for manufacturers. The composition of MSW shows mostly organic matter (45.3%), so composting is a good method for the treatment and production of soil amendment. The study presents the current scenario of MSWM, which will be helpful in creating aware- ness among the people.

Joshi et al. (2013) studied that Government of Maharashtra and BMC should work with their partners to promote source separation, achieve higher percentages of recycling and produce high quality compost from organics. Also, provisions should be made to handle the non-recyclable wastes that are being generated and will continue to be generated in the future. State Government should take a proactive role in leveraging their power to optimize resources. Mumbai should choose some options or a combination of them, like: Best address the issue of overall solid waste management, have the least impact on public health and environment And the Government should propose, Incineration technology upgradation to produce energy from waste.

Tchobanoglous (2014) explained that Integrated Solid Waste Management (ISWM) takes an overall approach to creating sustainable systems that are economically affordable, socially acceptable and environmentally effective. "Municipal solid waste" (MSW) is a term usually applied to a heterogeneous collection of wastes produced in urban areas, the nature of which varies from region to region. Urban wastes can be subdivided into two major components i.e. organic and inorganic. In general, the organic components of urban solid waste can be classified into three broad categories: putrescible, fermentable, and non-fermentable. Putrescible wastes tend to decompose rapidly and unless carefully controlled, decompose with the production of objectionable odours and visual unpleasantness. Integrated Solid Waste Management (ISWM) takes an overall approach to creating sustainable systems that are economically affordable, socially acceptable and environmentally effective. An integrated solid waste management system involves the use of a range of different treatment methods, and key to the functioning of such a system is the collection and sorting of the waste. Thus, all of the available treatment and disposal options must be evaluated equally and the best combination of the available options suited to the particular community should be chosen.

Rana et al. (2014) presented that the informal policy of encouraging the public to separate municipal solid waste and market it directly to the informal network appears to be better option. To tackle the waste generated urban local bodies should invest 35-50% of its funds on solid waste management. Waste management should not merely include the collection, transportation and processing of waste in fact need of the hour is to reduce the generation of waste. Our responsibility is to make people aware about the problem society is facing. It is very essential to keep streets and public places clean all the time. This is possible only if there is proper municipal solid waste management system and waste disposal is done in proper manner without hampering the natural resources.

Sasikumar et al. (2014) explained that removed items from the waste can be used as raw materials in the manufacturing of new products. Thus, from this definition, recycling occurs in three phases: first the waste is sorted and recyclables are collected; the recyclables are used to create raw materials. Sanitary Landfills are designed to greatly reduce or eliminate the risks that waste disposal may pose to the public health and environmental quality. They are usually placed in areas where land features act as natural buffers between the landfill and the environment. A landfill is divided into a series of individual cells and only a few cells of the site are filled with trash at any one time. This minimizes exposure to wind and rain. The daily waste is spread and compacted to reduce the volume, a cover is then applied to reduce odours and keep out pests. Here the care should be taken that when the landfill will reach to its capacity, it should be capped with an impermeable.

Mukherjee (2015) said that The Municipal Corporation of Greater Mumbai (MCGM) is formally responsible for the management of waste in the city. The prevailing approach has been one of collection and disposal that is, garbage is collected from communities by the municipal authorities. MCGM spends about Rs15-20lakh per day on collecting and transporting garbage and debris with municipal and private vehicles making about 2,000 trips every day. A dumping ground is, generally, a low-lying, and marshy area, which is located on the outskirts of a city, where there is, usually, no human population. We have, in our city, three dumping grounds which are located in the northern part of Mumbai at Gorai (Borivali), Mulund and Deonar. A fourth one at Chincholi has recently closed down. Amongst the three, Deonar is the largest dumping ground. All the dumping grounds are nearly 30-40km from South Mumbai which explains the huge costs on transportation. The increase in the population of the city has forced people to settle near the dumping grounds. This has led to the twin problems of people living in unhealthy conditions and protesting for the closure of the dumping grounds, as dumping causes health hazards for the people in the vicinity.

Sinha (2016) published in Gazette of India that sanitary landfill site shall be planned, designed and developed with proper documentation of construction plan as well as a closure planning a phased manner. In case a new landfill facility is being established adjoining an existing landfill site, the closure plan of existing landfill should form a part of the proposal of such new landfill. The landfill site shall be 100 meters away from river, 200 meters from a pond, 200 meters from Highways, Habitations, Public Parks and water supply wells and 20 km away from Airports or Airbase. However, in a special case, landfill site may be set up within a distance of 10 and 20 km away from the Airport/Airbase after obtaining no objection certificate from the civil aviation authority/ Air force as the case may be. The Landfill site shall not be permitted within the flood plains as recorded for the last 100 years, zone of coastal regulation, wetland, Critical habitat areas and sensitive eco-fragile areas. The ground water quality within 50 meters of the periphery of landfill site should be periodically monitored in summer, monsoon and post-monsoon period to ensure that the ground water is not contaminated.

Cristen (2017) said that In Maryland, local governments are generally responsible for managing the collection, processing, recycling, and disposal of solid waste. The process begins where the solid waste is generated. A person may transport their own solid waste directly to a transfer station or recycling or other processing facility or place the solid waste in a container for collection by a local government or a contracted private hauler. A local government may use its own employees or a private hauler to provide collection services or may allow private haulers to contract directly with customers. Generally local governments are more likely to provide residential collection services in more urban counties with higher population densities, while private subscription and self-hauling are prevalent in more rural counties. After processing, the materials are transported to a landfill or incinerator for disposal, or to compost or recyclables markets for reuse. Local governments use a dedicated enterprise fund, general tax revenue, or a combination of both to fund their solid waste management programs. The monies come from a variety of sources, including system benefit charges, tipping fees, impact fees, interest or investment income, bond revenues, and recycled commodity revenues. It can be concluded here that although Maryland facilities manage some solid waste imported from other jurisdictions, the State is a net exporter of solid waste and sends a significant amount for recycling or disposal in other states.

Douti (2017) concluded that this study was conducted in the Bawku Municipality of the Upper East, Ghana, with the view to assessing the factors that impede the management of solid waste. Questionnaires were submitted to 150 randomly selected households, while face-to-face semi-structured interviews were conducted with the municipal Waste Management Department and a private waste management company, Zoomlion Ghana Ltd. Data collected included components of solid waste generated, waste collection, transportation and final disposal methods, the challenges confronting waste management institutions, and respondents,' knowledge and perceptions of the waste management system and their attitudes towards it. Components of wastes generated were organic waste, paper waste and plastics. Factors that adversely affected waste collection and transportation systems were the inadequate supply of waste collection containers, the existence of a weak waste transportation system and a low patronage of the door-to-door collection method. The study further shows that the waste management institutions were faced with financial difficulties, understaffing and poor logistics and nature of roads, and social constraints. The study therefore suggests the development of a strategic plan for efficient waste management which revolves around these findings.

Kanfound (2017) explained that Constantine, with a population of 480,000 and containing 90,000 households, generated 164,250 tons of solid waste in 2015 in which domestic waste is the primary source. The aim of this study was to assess the situation of municipal solid-waste (MSW) management in Constantine. Actually, the collection and transportation of solid waste is managed by the municipality, with a small participation of the private sector. More than 90% of the municipality solid waste is disposed and treated in an environmentally sound manner (landfill). Unfortunately, there is a poor culture with respect to the 3R principles (reduce, reuse, recycle) in Constantine leading to a rapid growth of waste generation which has overwhelmed the capacity of the already saturated available landfill. The well-funded municipality has intensified its efforts in the generalization of collection and transportation of waste and eradication of dumpsites. However, there are still problems in the separation of MSW at the source as this activity is largely neglected. This is putting a lot of stress on the management of the landfill with regard to the rapid increase in waste generation.

Kumar (2017) concluded that Municipal solid waste hierarchy ranks the different ways in which we can treat and dispose of MSW in order of sustainability, or relative environmental benefits. From an economic point of view, applying the waste hierarchy on the collected MSW, under conventional circumstances, is useful for energy recovery, recycling, reusing and reducing waste at the minimum. For the final disposal inevitably, landfill has become the largest component in the waste management pyramid and in directly for odour management. In addition, due to its simple and low-cost technology, landfill and its g asses is highly preferred consumption in most developing nations. The waste hierarchy must be used as a basis of waste management strategy, focuses to minimize and reduce the pre-landfill quantity of waste. This simplified the list of priorities helps some waste management of some over others (reused over recycling, recycling over disposal). If this hierarchy is adopted, it will help in minimization of odour generation at the MSW landfill site. However, it is essential to effectively achieve odour abatement at MSW landfill site to avoid above manifestation with reference to mal odorous.

Yadav (2017) explained that Industrialization becomes very significant for developing countries like India having large number of population. Rapid increase in urbanization and per capita income lead to high rate of municipal solid waste generation. In recent times, E-waste and plastic waste also contribute considerably to total waste stream due to utilization of electronic and other items. These wastes may cause a potential hazard to human health or environment if any of the aspects of solid waste management is not managed effectively. In India, approach towards Solid waste management is still unscientific. Even today, large portion of solid waste is dumped indiscriminately on outskirts of towns or cities without any prior treatment. This leads to groundwater contamination and increase in air pollution due to leachate percolation and release the gases. Various study reveals that out of total solid waste, 80% can be utilized again either by recycling or reusing. Improper waste segregation and other factors lead recycling sector to work on outdated technology. However, plastic and paper recycling have been especially growing due to continuous increasing consumption of both the commodities. This study describes about current status of municipal solid waste management in different regions of India.

2.3 Summary

Research on disposal of municipal solid waste shows that various attempts for improving the management related collection, transport, disposal of solid waste are actively coming in practices which is eco-friendly and do not cause any health hazard. Review of literature survey shows various properties (physical, chemical, biological) of waste are properly studied and accordingly their reuse, recycle, recover, reduction is brought in practice but still there is research gap and that is improper management and planning for disposal of MSW without acquiring excel land excessive land. And this is the challenging problem to municipal authorities due to rapidly increasing population and pertaining to that increasing solid waste day by day.

Chapter 3

Methodology

3.1 General

In methodology, future population after 3 decades and rate of solid waste generation is calculated from the available data.

The following methodology adopted to achieve the objectives of the proposed work:

1. Forecasting the data on the basis of available data of previous decades and the rate of generation of solid waste.
2. Collecting data in tabular form and applying knowledge of assignment problems to assign the proper method of disposal.
3. Route optimization of transporting solid waste by dynamic programming.
4. Enlisting the methods of solid waste disposal and selecting any one method suitable for Panvel area which optimizes time, cost without causing harm to public health, environment, ecosystem.

Figure 3.1 shows flow chart of methodology adopted to achieve the objectives of proposed work like forecasting the data and rate of solid waste generation, suggesting the eco-friendly method of solid waste disposal.

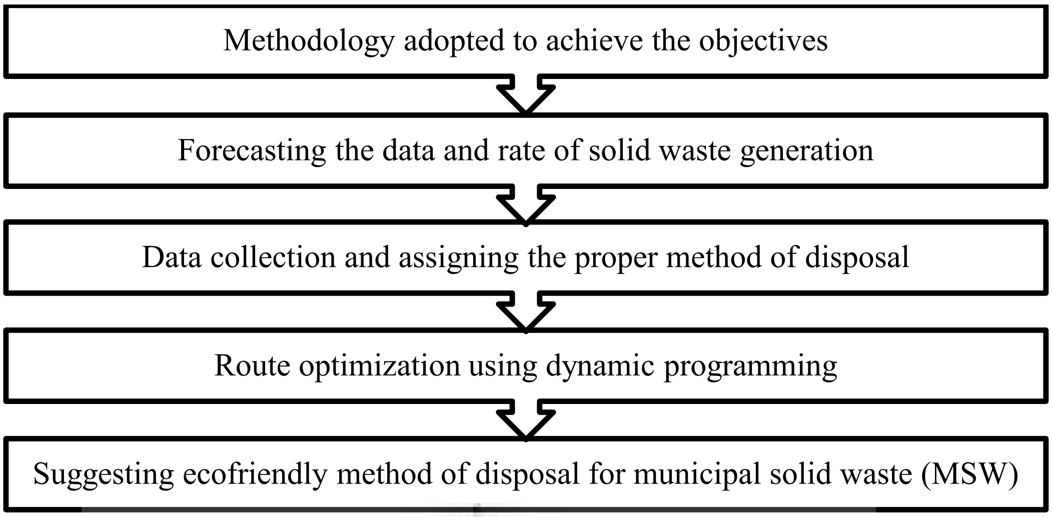

Figure 3.1 Flow chart of methodology adopted to achieve the objectives

This flow chart shown in above Figure 3.1 gives detail idea about methodology adopted to achieve the objectives of proposed work.

Optimizing connections in transportation networks is a popular problem that arises in many different scenarios, such as car journeys, public transportation, or logistics optimization. People expect computers to assist them with these problems in a comfortable and fast way, whether they are at home, at work, or on a journey. This creates a demand for efficient algorithms to solve these problems. We see that in the existence of many online routing services, mobile navigation devices, and industrial tour planners.

For Assignment model theorem is used that, if a number is added to or subtracted from all of the entries of any one row or column of a cost matrix, then on optimal assignment for the resulting cost matrix is also an optimal assignment for the original cost matrix.

Table 3.1 below shows the population data of last six decades from which we can forecast the population in future (Ref: Panvel Municipal Corporation, PMC).

Table 3.1 Last six decades population data

Year	1961	1971	1981	1991	2001	2011
Population	18130	26602	37073	58986	104031	180020

This data is collected from Panvel Municipal Corporations. By using this data, we can easily forecast the population after 3 decades.

3.2 Methods of population forecasting

By using the methods of population forecasting population after 3 decades in year 2041 can be calculated.

Following are the methods of population forecasting which are used for this work:

1. Arithmetical increase method
2. Geometrical increase method
3. Incremental increase method
4. Graphical method

3.2.1 Arithmetical increase method

This method is suitable for large and old city with considerable development. If it is used for small, average or comparatively new cities, it will give lower population estimate than actual value. In this method the average increase in population per decade is calculated from the past census reports. This increase is added to the present population to find out the population of the next decade. Thus, it is assumed that the population is increasing at constant rate.

Hence, $dP/dt = C$ i.e., rate of change of population with respect to time. Therefore, Population after n^{th} decade will be

$$P_n = P + n\,C \tag{1}$$

Where, P_n is the population after 'n' decades and 'P' is present population.

3.2.2 Geometrical increase method

In this method the percentage increase in population from decade to decade is assumed to remain constant. Geometric mean increase is used to find out the future increment in population. Since this method gives higher values and hence should be applied for a new industrial town at the beginning of development for only few decades. The population at the end of n^{th} decade P_n can be estimated as

$$P_n = P\,(1 + I_G\,\%\,)\,n \tag{2}$$

Where, I_G = geometric mean (in percentage), P = Present population, n = no. of decades.

3.2.3 Incremental increase method

This method is modification of arithmetical increase method and it is suitable for an average size town under normal condition where the growth rate is found to be in increasing order. While adopting this method the increase in increment is considered for calculating future population. The incremental increase is determined for each decade from the past population and the average value is added to the present population along with the average rate of increase. Hence, population after n^{th} decade is

$$P_n = P + nX + (0.5\,n^2 + 0.5\,n)\,Y \qquad (3)$$

Where, P_n = Population after n^{th} decade X = Average increase Y = Incremental increase

3.2.4 Graphical method

In this method, the populations of last few decades are correctly plotted to a suitable scale on graph. The population curve is smoothly extended for getting future population. This extension should be done carefully and it requires proper experience and judgment. The best way of applying this method is to extend the curve by comparing with population curve of some other similar cities having the similar growth condition.

3.3 Route optimization

In transportation systems, there exists a high degree of coupling between the vehicle capabilities and the network definition, as realized in the definition of the operations. When designing a complex transportation system, such as an aircraft transportation network, it is beneficial to define the system boundary to include the network definition as well as the operations into the vehicle design optimization. This expansion of the system definition allows for the coupling between the vehicle design and network definition to be exploited, thereby reducing inefficiencies in the transportation system and resulting in the optimal transportation architecture. The operations of a transportation system determine how the vehicle performs on a given route and is defined by two sets of equations: capability and capacity constraints. The capability constraints govern the ability of a specified vehicle to travel a given path. For the aircraft transportation problem, the capability constraints are simply a constraint on the distance that an aircraft can travel without refuelling.

3.4 Assignment method

The assignment problem is a particular class of transportation linear programming problems with the supplies and demands equal to integers. Since all supplies, demands, and bounds on variables are integers, the assignment problem relies on an interesting property of transportation problems that the optimal solution will be entirely integers. Application of the assignment model are numerous and widespread in our daily life. It is not just limited to assignment jobs to employees or machines; its scope is wide spread. Presently, in the literature, we have used four methods for solving assignment problem. They are Simplex method, Enumeration method, Transportation method and Hungarian method. Among them all, Hungarian Method turns out to be the best. In the past; many researchers already have worked with this method. Basirzadh worked and developed a Hungarian like method knows as Ones Assignment method which maximizes or minimizes the objective function. Muley and Ghadhe presented a new step in Basirzadeh's method and hence named it revised Ones assignment method. H. Gamel also brought to light the drawbacks of one assignment method with some modification. Although these algorithms are efficient in general, they possess drawbacks which can lead to poor performance

3.5 Summary

In methodology from the collected data forecasting of future population done after 3 decades and from that rate of solid waste generation is calculated. Route optimization technique is used for selecting the optimum route for transportation of solid waste. Then according to characteristics of solid waste different methods are assigned to different sort of solid waste.

Chapter 4

Study Area and Data Collection

4.1 General

Data for the respective work is collected from Panvel Municipal Corporation (PMC). Area of Panvel is 29 sq. mile but population is situated in 12.17 sq. mile area, rest 16.83 sq. mile area is under marketing, commercial, communication development according to Panvel Municipal Corporation (PMC) as well as last six decades population data is collected from Panvel Municipal Corporation (PMC) by using this data population and rate of solid waste generated by that population after 3 decades can be calculated.

4.2 Statistical record of study area (Panvel)

All statistical record like data of population of last six decades, map of Panvel area, total area of Panvel, area under residential zone and commercial zone, routes of places in Panvel with route distances, solid waste collection and dumping yard, methods of dumping adopted, impact of adopted solid waste disposal method on environment have been collected.

Table 4.1 shows the population data of last six decades collected from Panvel Municipal Corporation (PMC) by which we can forecast the population after 3 decades (Ref: Panvel Municipal Corporation, PMC)

Table 4.1 Last six decades population data, Panvel

Year	1961	1971	1981	1991	2001	2011
Population	18130	26602	37073	58986	104031	180020

Table 4.2 shows Status of Solid Waste Disposal in Municipal Corporations of Maharashtra (as on March-2008). This table shows various municipal corporation cities of urban and suburban areas as well as quantity of solid waste generated by the cities and method of disposal used for the generated solid waste (Ref: http.www.municipalwastedisposalstatus.maha.in)

Table 4.2 Status of Solid Waste Disposal in Municipal Corporations of Maharashtra

Sr. No	Municipal corporation	Population	Quantity (MT/D)	Mode of Disposal
1	Mumbai	11914393	7000	Composting
2	Thane	1600000	600	Landfill
3	Kalyan and Dombivali	1400000	550	Dumping
4	Ulhasnagar	473000	300	Landfill
5	Navi Mumbai	1043882	500	Landfill
6	Pune	4000000	1000	Composting

Table 4.2 helps to calculate rate of solid waste generated Kg/capita/day. This information helps to calculate quantity of municipal solid waste daily generated by the population. This information will help to calculate quantity of municipal solid waste daily generated by the population.

Table 4.3 shows Quantity of solid waste disposed in all Municipal councils in the state tabulated region wise (MPCB regional offices) as bellow- (as on March-2008). This table also shows various districts of urban and suburban areas and the quantity of solid waste generated as well as methods of solid waste disposal used in practice. (Ref: http.www. municipalwastedisposal status.mpcb.in)

Table 4.3 Quantity of solid waste disposed in all Municipal councils

Region	Municipal Councils	Population	Quantity (MT/D)	Mode of disposal
Raigad	Khopoli, Panvel, Pen, Karjat, Matheran, Mahad, Shriwardhan, Roha, Murud-janjira, Alibag	323983	77	Open dumping, land filling, composting
Thane	Dahanu, Jawahar, Palghar, Manikpur, Navghar, Vasai, Virar, Nallasopara	578124	219	Open dumping

Table 4.3 above shows various districts and major cities in each district as well as total population of the district as per last decade and pertaining to that population quantity of MSW daily disposed and adopted method for disposal is mentioned which helps to calculate rate of solid waste generated Kg/capita/day. This information will help to calculate quantity of municipal solid waste daily disposed by municipal council of Raigad district.

Figure 4.1 shows Map of Panvel area (Source: www.roadmappanvel.com) in which all sectors and routes of the area can be seen and it also helps for deciding the routes of transportation and optimum route. This map helps for route optimization and deciding the shortest path which will save time and fuel.

Figure 4.1 Map of Panvel area

Figure 4.1 above helps to decide routes for transportation of municipal solid waste and location of all places in Panvel area. This map shows major roads and other roads connected to major roads and passing through the all areas of Panvel which will cover all the locations in Panvel while deciding the route of transportation for MSW (Municipal Solid Waste) collection.

4.3 Details of Taloja dumping ground

Municipal solid waste generated from Panvel is collected and then transported to Taloja (Ghotgaon) for final disposal of waste. There landfilling, open dumping and incineration methods are used for disposal of waste which are unhygienic and hazardous to health as well as not at all eco-friendly processes.

For this work we visited on 19th February 2017 at dumping ground, Ghotgaon, Taloja and collected all information required for the work.

Table 4.4 shows analysis report of municipal solid waste which is collected from disposal plant, Taloja. From which calculation for Landfilling, Composting & incineration wastes can be done (Source: Taloja dumping ground office record, CIDCO).

Table 4.4 Municipal solid waste (MSW) analysis report

Parameter	Weight (gm.)	(%) Details
Plastic	490	11.06 %
Rubber	70	0.98%
Fuel	2210	17.93%
Decomposable fibre	580	3.02%
Organic	1540	27.97%
Food waste	770	16.67%
Inert	4850	4.11%
Glass	250	2.91%
Metal	200	3.1%
Hard plastic	510	0.66%
Coconut	1580	12.10%
Total	13050	99.95%

Such that Table 4.4 shows analysis report of municipal solid waste from which percentage of various content present in MSW are approximately sorted for per day collection and segregation of waste.

Table 4.5 shows about area of land requires for facilities, landfilling and capacity of landfilling proposed up to 15.5 years. CIDCO (City and Industrial Development Corporation) has proposed plan for 15.5 years of landfilling and as per the load of landfilling requirement of waste land to them which is shown below in the Table 4.5

Table 4.5 Salient features of Taloja dumping ground

Sr. No	Description	Taloja plant details
1	Total area of facility	14 Hectors
2	Area of landfill	5.5 Hectors
3	Expected life of landfill	15.5 Years

4	Capacity of landfill	365000 MT/Year
5	No. Of landfill cells	5 No's
6	Method of treatment	Aerobic composting by windrow method
7	Weight bridge	40 MT Capacity
8	Platform for composting	1.3 Hectors
9	Compost plant capacity	65 MT/ Shift
10	Leachate pond	25M X 25 M

Table 4.5 shows CIDCO (City and Industrial Development Corporation) has proposed plan for 15.5 years of landfilling and 1.3 Hectors for composting for the same years of landfilling and the capacity of the composting plant is 65 MT.

4.4 Summary

Data for the respective work is collected from Panvel Municipal Corporation (PMC). Area of Panvel is 29 sq. mile but population is situated in 12.17 sq. mile area, rest 16.83 sq. mile area is under marketing, commercial, communication development according to Panvel Municipal Corporation (PMC). As well as visited to Taloja dumping ground where municipal solid waste of Panvel is dumped and collected information from them related this work.

Chapter 5

Results and Discussions

5.1 General

In result and discussion, land required for landfilling, composting, incineration is calculated from year 2017 to 2041 (i.e. 25 years) then comparison is done between proposed planning and CIDCO planning, pertaining to that modified planning is introduced here in this work. CIDCO planning is for 15.5 years from 2017 onwards and here we have introduced planning for 25 years from 2017 onwards.

5.2 Population forecasting

Table 5.1 shows Arithmetical increase method (AIM), Geometrical increase method (GIM), Incremental increase method (IIM) for forecasting population after 3 decades in year 2041. This is calculated with reference to the formulas mentioned earlier in the article of 3.2.1, 3.2.2 and 3.2.3 for Arithmetical increase method, Geometrical increase method and Incremental increase method respectively.

Table 5.1 Arithmetical increase, Geometrical increase and Incremental increase method

Year	Population	AIM Increase in Population (d)	GIM Percentage Increase in Population (r)	IIM Incremental Increase in Population (t)
1961	18130			
		8472	46.73 %	
1971	26602			1999
		10471	39.36 %	
1981	37073			11442
		21913	59.11 %	
1991	58986			23132
		45045	76.37 %	
2001	104031			30944
		75989	73.04 %	
2011	180020			
Total		161890		67517
Population after 3 decades **P_{2041}**		**277154**	**722531**	**378430**

Hence, the above Table 5.1 shows maximum population in year 2041 will be 722531 by geometrical increase method. This data is collected form Panvel Municipal Corporation (PMC) as shown in chapter 4, Table 4.1, from which population after 3 decades in 2041 is forecasted here.

5.2.1 Graphical method

Figure 5.1 shows Graphical method for forecasting population after 3 decades in year 2041. Graph shows X-axis for decades (1961-2041) and Y-axis for population.

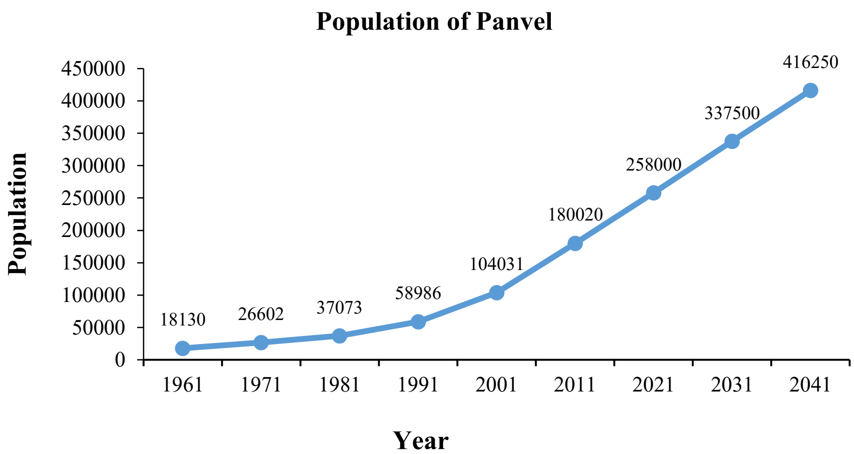

Figure 5.1 Graphical method

Fig. 5.1 shows the graph of Panvel's Population, where X-axis shows decades from 1961-2041 and Y-axis shows growth in population on interval of 200000 people. From this Fig. 5.1 it can be seen that population in year 2041 will be approximately 416250 people i.e. $\mathbf{P_{2041} = 420000}$. This graph is plotted with reference to the Table 3.1, which is a data of population record from year 1961 to year 2011 and from this population in the year 2041 is forecasted.
Average Population of arithmetical increase, geometrical increase, incremental increase and graphical method = 449529
From this Average population is 449529 and maximum population by Geometrical increase method is 722531 so, let's choose the higher value of population i.e. $\mathbf{P_{2041} = 722531}$

Table 5.2 below shows area of Panvel and population of the area after 3 decades in year 2041.

Table 5.2 Area of Panvel and population of the area in year 2041.

Sr. No.	Particulars	Area	Total Population
1.	Residential area	12.17 $mile^2$	722531
2.	Per sq. mile of residential area	1 $mile^2$	59370
3.	Total area of Panvel	29 $mile^2$	1721730

From this Table 5.2 above it can be seen that population of 29 $mile^2$ Panvel area after 3 decades in year 2041 will be about **1721730** people. In which from calculated population for per square mile area totally 29 square mile area population can be predicted in which future expansion of Panvel area after 3 decades is taken in consideration.

5.3 Calculation of Landfilling:

From the reference of **Table 4.2 and Table 4.3** rate of solid waste generation is, (77 MTPD/323983) = 0.24 Kg/capita/day and (500MTPD/1043882) = 0.48 Kg/capita/day respectively. So, the average rate of solid waste generation from above values = 0.36 Kg/capita/day.

Table 5.3 shows details of quantity of solid waste generated by last decade i.e. year 2011 population and the quantity of solid waste generated by population after 3 decades in year 2041. Pertaining to that the expected quantity of solid waste per year is calculated.

Table 5.3 Quantity of solid waste and facility of landfilling

Sr. No.	Details	Calculation	Values and Remark
1.	Quantity of solid waste generated in last decade by the population of Panvel area.	180020 X 0.36	64.81 MT/D (64.81 MT/D < 77 MT/D, Hence OKAY)
2.	Quantity of solid waste will generate after 3 decades, in year 2041 for Panvel area	1721730 X 0.36	619.82 MT/D
3.	Maximum landfilling could be done in year 2041	619.82 X 365 days	226235 MT/ year
4.	So, the facility of landfilling need to provide is approximately,		230000 MT/ year

Table 5.3 above shows the calculation of last decade population in year 2011 i.e. 180020 per day rate of solid waste generation obtained by multiplying the average rate of solid waste generation i.e. 0.36 Kg/capita/day. And solid waste generated after 3 decades in year 2041 by the population of 1721730. Which is obtained by multiplying the average rate of solid waste generation i.e. 0.36 Kg/capita/day with population. Pertaining to that the facility of landfilling need to provide is approximately calculated as 230000 MT/ year.

Table 5.4 shows percentage of solid waste for landfilling disposal from the total available solid waste. Which are obtained from calculation of Table 4.4 and the quantity of solid waste generated after 3 decades. Which are as follows:

Table 5.4 Landfill Waste in Percentage (%)

Components	Landfill waste in percentage (%)
Plastic	11.06 %
Rubber	0.98 %
Inert	4.11%
Hard plastic	0.66%
Total	16.81% ≈ 17%

Such that Table 5.4 shows totally 17 % solid waste can be utilized for landfilling disposal from the total available solid waste which is addition of sorted municipal solid waste (MSW) and waste proceeded for final landfilling. This value 17 % can be used for the calculation of landfilling waste could be generated and area of landfill required after 25 yrs.

Table 5.5 shows Calculation of landfilling for 25 years up to year 2041 which can be obtained by standard nominal value of landfill per cubic meter is about to 0.9 MT. Whereas, in the Table 5.5 below geometrical increment is obtained by interpolation method for subsequent year, total waste generated is obtained by per day rate of solid waste generation multiplying with population, 17% of total waste for landfill per day is taken into consideration from Table 5.4, landfill per year is calculated by multiplying with 365 days, height of landfill is taken 0.9 m (as per CIDCO norms it shouldn't exceed 1.5 m)

Table 5.5 Calculation of landfilling for 25 years up to 2041

Sr. No	Year	Population	Geometrical increment	Total waste MT/day	17% of total Waste for Landfill MT/day	Landfilling per year MT/year	Height of Landfill	Area of landfill (m^2)	Area of landfilling for 5 year (m^2)	Area (Hec)	Area required (2017 to 2041)
1	2017	243661	254268	87.71796	14.912053	5442.8994	0.9 x 6	1007.9443	5478.4979	0.547	**4.54 Hec**
2	2018	254268	264875	91.53648	15.561202	5679.8386	0.9 x 6	1051.822			
3	2019	264875	275482	95.355	16.21035	5916.7778	0.9 x 6	1095.6996			
4	2020	275482	286089	99.17352	16.859498	6153.7169	0.9 x 6	1139.5772			
5	2021	286089	298565	102.99204	17.508647	6390.6561	0.9 x 6	1183.4548			
6	2022	298565	311041	107.4834	18.272178	6669.345	0.9 x 6	1235.0639	6691.41	0.669	
7	2023	311041	323517	111.97476	19.035709	6948.0339	0.9 x 6	1286.6729			
8	2024	323517	335993	116.46612	19.79924	7226.7227	0.9 x 6	1338.282			
9	2025	335993	348469	120.95748	20.562772	7505.4116	0.9 x 6	1389.891			
10	2026	348469	362814	125.44884	21.326303	7784.1005	0.9 x 6	1441.5001			
11	2027	362814	377159	130.61304	22.204217	8104.5391	0.9 x 6	1500.8406	8097.6077	0.809	
12	2028	377159	391504	135.77724	23.082131	8424.9777	0.9 x 6	1560.1811			
13	2029	391504	405849	140.94144	23.960045	8745.4164	0.9 x 6	1619.5215			
14	2030	405849	420194	146.10564	24.837959	9065.855	0.9 x 6	1678.862			
15	2031	420194	436408	151.26984	25.715873	9386.2936	0.9 x 6	1738.2025			
16	2032	496408	512622	178.70688	30.38017	11088.762	0.9 x 6	2053.4744	10938.091	1.093	
17	2033	512622	528836	184.54392	31.372466	11450.95	0.9 x 6	2120.5463			
18	2034	528836	545050	190.38096	32.364763	11813.139	0.9 x 6	2187.6183			
19	2035	545050	561264	196.218	33.35706	12175.327	0.9 x 6	2254.6902	14196.291	1.419	
20	2036	561264	579347	202.05504	34.349357	12537.515	0.9 x 6	2321.7621			
21	2037	650197	668280	234.07092	39.792056	14524.101	0.9 x 6	2689.6483			
22	2038	668280	686363	240.5808	40.898736	14928.039	0.9 x 6	2764.4516			
23	2039	686363	704448	247.09068	42.005416	15331.977	0.9 x 6	2839.2549			
24	2040	704448	722531	253.60128	43.112218	15735.959	0.9 x 6	2914.0666			
25	2041	722531	740614	260.11116	44.218897	16139.897	0.9 x 6	2988.8699			

From the Table 5.5 Landfill area required for 25 years (2017-2041) will be 4.54 Hectors. Such that area required for landfill is optimizing which saves land as well as investment of cost for land in present and in future also.

5.4 Calculation of Composting Area

Table 5.6 is collected from Taloja dumping ground office record, CIDCO which shows percentage of solid waste for composting disposal from the total available solid waste. Which is collected from Table 4.4 and the quantity of solid waste generated after 3 decades is calculated using this data. Which are as follows *(Ref: Taloja dumping ground office record, CIDCO)*

Table 5.6 Composting Waste in Percentage (%)

Composting waste in percentage (%)	
Decomposable fibres waste	3.02 %
Organic waste	27.97 %
Food waste	16.67 %
Total waste	**47.66 % ≈ 50 %**

Table 5.6 shows totally 50 % solid waste can be utilized for composting disposal from the total available solid waste. This value 50 % can be used for calculation of composting waste could be generated and area of land required after 25 yrs. for composting.

Table 5.7 shows Calculation of composting area for 25 years up to year 2041. Which can be obtained by standard nominal value of composting per cubic meter is about to 0.7 MT. Whereas, in the Table 5.7 below geometrical increment is obtained by interpolation method for subsequent year, total waste generated is obtained by per day rate of solid waste generation multiplying with population, 50 % of total waste for composting per day is taken into consideration from Table 5.6, compost per year is calculated by multiplying with 365 days, in 1 cu. m of trench 0.7 MT composting material can be laid as per MSW disposal norms complied by Taloja dumping ground pertaining to that total volume of trench required for composting is calculated, height of composting windrow is taken as 2 m and from which area of land required for composting is calculated, for material stacking purpose 1.5% additional area is taken into account and number of windrows required is total area of composting land to the area of one windrow (100 m X 08 m).

Table 5.7 Calculation of composting area for 25 years

Sr. No.	Year	Population	Geometrical increment	Waste/day MT/day	Composting 50 %	Per year	Half year	Volume (m^3)	Area (m^2)	Total area (m^2)	No. of Windrows
1	2017	243661	254268	87.72	43.86	16008.53	8004.26	11434.66	5717.33	5803.09	8
2	2018	254268	264875	91.54	45.77	16705.41	8352.70	11932.43	5966.22	6055.71	8
3	2019	264875	275482	95.36	47.68	17402.29	8701.14	12430.21	6215.10	6308.33	8
4	2020	275482	286089	99.17	49.59	18099.17	9049.58	12927.98	6463.99	6560.95	9
5	2021	286089	298565	102.99	51.50	18796.05	9398.02	13425.75	6712.87	6813.57	9
6	2022	298565	311041	107.48	53.74	19615.72	9807.86	14011.23	7005.61	7110.70	9
7	2023	311041	323517	111.97	55.99	20435.39	10217.70	14596.71	7298.35	7407.83	10
8	2024	323517	335993	116.47	58.23	21255.07	10627.53	15182.19	7591.10	7704.96	10
9	2025	335993	348469	120.96	60.48	22074.74	11037.37	15767.67	7883.84	8002.09	11
10	2026	348469	362814	125.45	62.72	22894.41	11447.21	16353.15	8176.58	8299.22	11
11	2027	362814	377159	130.61	65.31	23836.88	11918.44	17026.34	8513.17	8640.87	11
12	2028	377159	391504	135.78	67.89	24779.35	12389.67	17699.53	8849.77	8982.51	12
13	2029	391504	405849	140.94	70.47	25721.81	12860.91	18372.72	9186.36	9324.16	12
14	2030	405849	420194	146.11	73.05	26664.28	13332.14	19045.91	9522.96	9665.80	13
15	2031	420194	436408	151.27	75.63	27606.75	13803.37	19719.10	9859.55	10007.45	13
16	2032	496408	512622	178.71	89.35	32614.01	16307.00	23295.72	11647.86	11822.58	15
17	2033	512622	528836	184.54	92.27	33679.27	16839.63	24056.62	12028.31	12208.73	16
18	2034	528836	545050	190.38	95.19	34744.53	17372.26	24817.52	12408.76	12594.89	16
19	2035	545050	561264	196.22	98.11	35809.79	17904.89	25578.42	12789.21	12981.05	17
20	2036	561264	579347	202.06	101.03	36875.04	18437.52	26339.32	13169.66	13367.20	17
21	2037	650197	668280	234.07	117.04	42717.94	21358.97	30512.82	15256.41	15485.25	20
22	2038	668280	686363	240.58	120.29	43906.00	21953.00	31361.43	15680.71	15915.92	20
23	2039	686363	704448	247.09	123.55	45094.05	22547.02	32210.04	16105.02	16346.59	21
24	2040	704448	722531	253.60	126.80	46282.23	23141.12	33058.74	16529.37	16777.31	21
25	2041	722531	740614	260.11	130.06	47470.29	23735.14	33907.35	16953.67	17207.98	22

From the Table 5.7 Composting area required for 25 years (2017-2041) = 1.72 Hectors.

Hence Total area = 5803.09 sq. m, No of windrows =08

Such that area required for compost is optimizing which saves land as well as investment of cost for land in present and in future also. Composting Manure is a fertilizer product which can helps to generate revenue and can also help in agriculture for increasing yield.

5.5 Calculation of Incineration Area

Table 5.8 below shows Calculation of incineration area for 25 years up to year 2041. Which can be obtained by standard nominal value of 0.35 MT per cubic meter of incineration. Whereas, in the Table 5.8 below geometrical increment is obtained by interpolation method for subsequent year, total waste generated is obtained by per day rate of solid waste generation multiplying with population, remaining 33 % waste of total waste is taken for incineration and according to 0.35 MT per cubic meter required for incineration by interpolation volume of waste for incineration is calculated, considering 2m height of incineration waste pile the area required for incineration is calculated.

Table 5.8 Calculation of incineration area for 25 years

S.N.	Year	Population	Geometrical increment	Waste/day MT/day	Incineration 33 % MT/day	Volume (m^3)	Area (m^2)
1	2017	243661	254268	87.72	28.95	82.72	41.36
2	2018	254268	264875	91.54	30.21	86.31	43.15
3	2019	264875	275482	95.36	31.47	89.91	44.95
4	2020	275482	286089	99.17	32.73	93.51	46.75
5	2021	286089	298565	102.99	33.99	97.11	48.55
6	2022	298565	311041	107.48	35.47	101.34	50.67
7	2023	311041	323517	111.97	36.95	105.58	52.79
8	2024	323517	335993	116.47	38.43	109.81	54.91
9	2025	335993	348469	120.96	39.92	114.05	57.02
10	2026	348469	362814	125.45	41.40	118.28	59.14
11	2027	362814	377159	130.61	43.10	123.15	61.57
12	2028	377159	391504	135.78	44.81	128.02	64.01
13	2029	391504	405849	140.94	46.51	132.89	66.44
14	2030	405849	420194	146.11	48.21	137.76	68.88
15	2031	420194	436408	151.27	49.92	142.63	71.31

16	2032	496408	512622	178.71	58.97	168.50	84.25
17	2033	512622	528836	184.54	60.90	174.00	87.00
18	2034	528836	545050	190.38	62.83	179.50	89.75
19	2035	545050	561264	196.22	64.75	185.01	92.50
20	2036	561264	579347	202.06	66.68	190.51	95.25
21	2037	650197	668280	234.07	77.24	220.70	110.35
22	2038	668280	686363	240.58	79.39	226.83	113.42
23	2039	686363	704448	247.09	81.54	232.97	116.49
24	2040	704448	722531	253.60	83.69	239.11	119.55
25	2041	722531	740614	260.11	85.84	245.25	122.62

From the Table 5.8 area required for Incineration process for 25 years = 0.0122 Hector and area for dumping solid waste = 41.36 m^2. Such that area required for incineration is optimizing which saves land as well as investment of cost for land in present and in future also.

5.6 Route Optimization:

Route optimization helps to find shortest route for transportation and also saves time of transportation. Fig. 5.2 shows Dynamic Programming for route optimization which shows highlighted places of Panvel area and route distances between them in kilometres (km.) for the effective road transportation of vehicles carrying waste. The name of places on route are follows: 1. Panvel bus depot 2. Garden hotel 3. Sainagar 4.Sec. 10 Khanda colony 5. HOC 6. Khanda colony signal (island) 7. Khandeshwar 8. Khandagaon 9. Khanda colony sec. 17 10. Kalamboli circle 11. Kamothe 12. Taloja 13. SW disposal plant, Ghotgaon, Taloja.

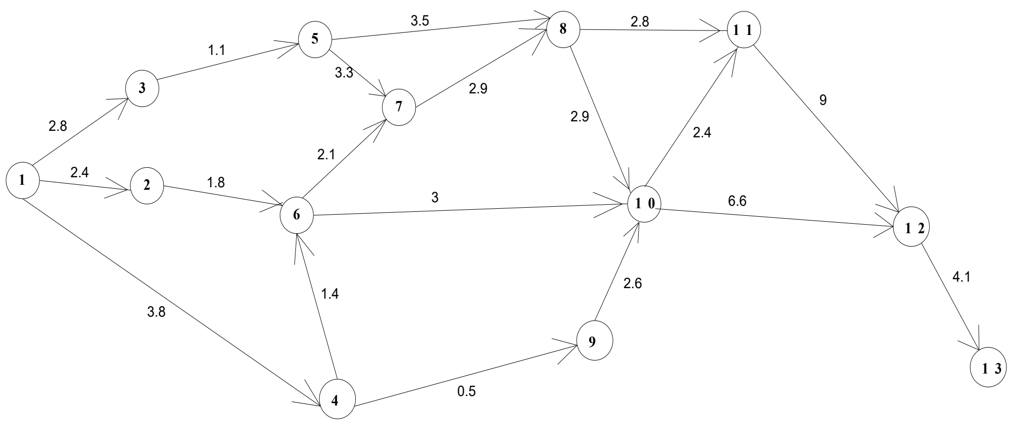

Figure 5.2 Dynamic Programming for route optimization

From the above Figure 5.2 route 1-2-6-7-8-11-12-13 showing 25.1 km distance, route 1-3-5-7-8-11-12-13 showing 26 km distance, route 1-2-6-10-12-13 showing 17.9 km distance, route 1-4-9-10-12-13 showing 17.6 km distance and route 1-4-6-10-12-13 showing 18.9 km distance. Fig 5.3 shows Optimum route selected for the transportation of vehicles which carrying waste from Panvel area to Taloja dumping ground.

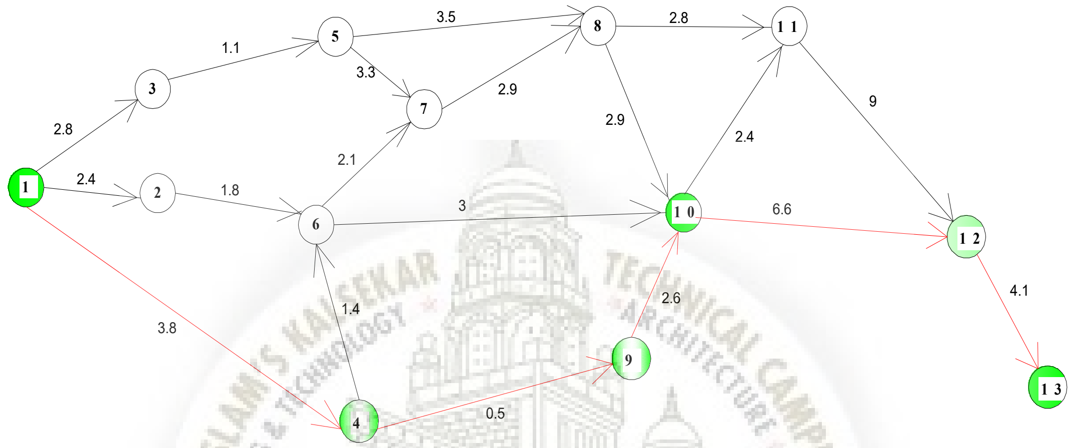

Figure 5.3 Optimum Route selection

Such that from above Fig 5.3, optimum route selected is 1 – 4 – 9 – 10 – 12 – 13 (Panvel bus depot - Sec. 10 Khanda colony - Khanda colony sec. 17 - Kalamboli circle - Taloja - SW disposal plant, Ghotgaon, Taloja). This route saves distance and time of transportation which ultimately leads to save the cost and time of transportation of collected municipal solid waste (MSW).

5.7 Application of Primavera

Primavera is a comprehensive, high performance, multi project planning and control software. It provides unlimited resources and unlimited number of target plans, multiple ways to organise, filter and sort activities, projects and resources planning. Here in this work Primavera software is used for selecting the optimum route of transportation of municipal solid waste from Panvel to dumping ground at Ghotgaon, Taloja.

5.8 Report generated through Primavera

In this work, using Primavera software, dynamic programming for route optimization from Panvel to Ghotgaon, Taloja is achieved. Fig. 5.4 shows Dynamic Programming for route optimization which shows highlighted places of Panvel area and routes for the effective road transportation of vehicles carrying waste.

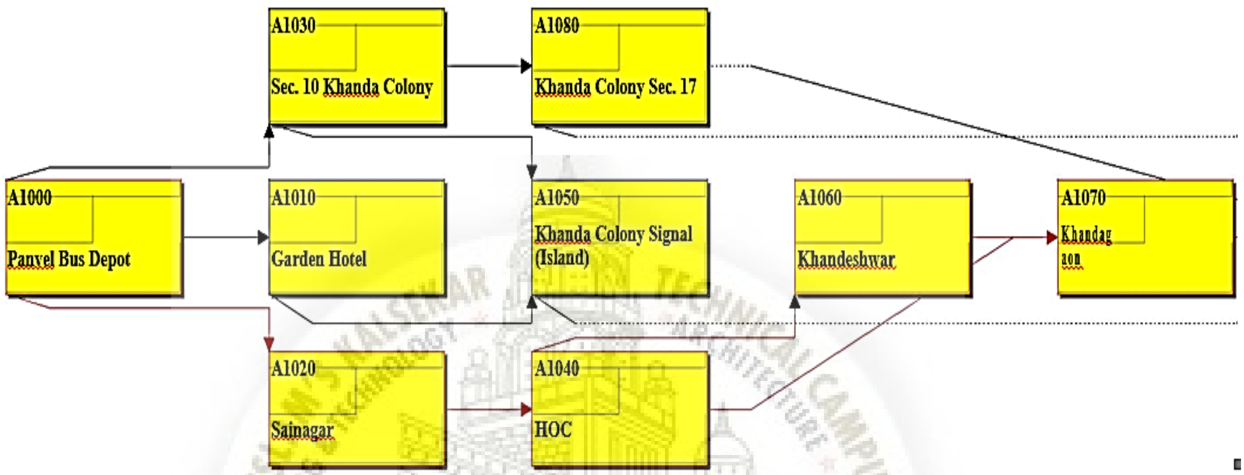

Figure 5.4 Dynamic Programming for route optimization using PRIMAVERA software

Figure 5.4 shows the name of places on route of Panvel to Ghotgaon, Taloja which helps to determine the route of transportation for municipal solid waste (MSW). Which is as follows: [**A1000.** Panvel bus depot **A1010.** Garden hotel **A1020.** Sainagar **A1030.** Sec.10 Khanda colony **A1040.** HOC **A1050.** Khanda colony signal (island) **A1060.** Khandeshwar, Kamothe **A1070.** Khandagaon, SW disposal plant, Ghotgaon, Taloja **A1080.** Khanda colony sec. 17]

Fig. 5.5 shows the Primavera software output, which gives the result same as calculated result of optimized route by using critical path method earlier in article 5.6. This route saves distance and time of transportation which ultimately leads to save the cost and time of transportation of collected municipal solid waste (MSW).

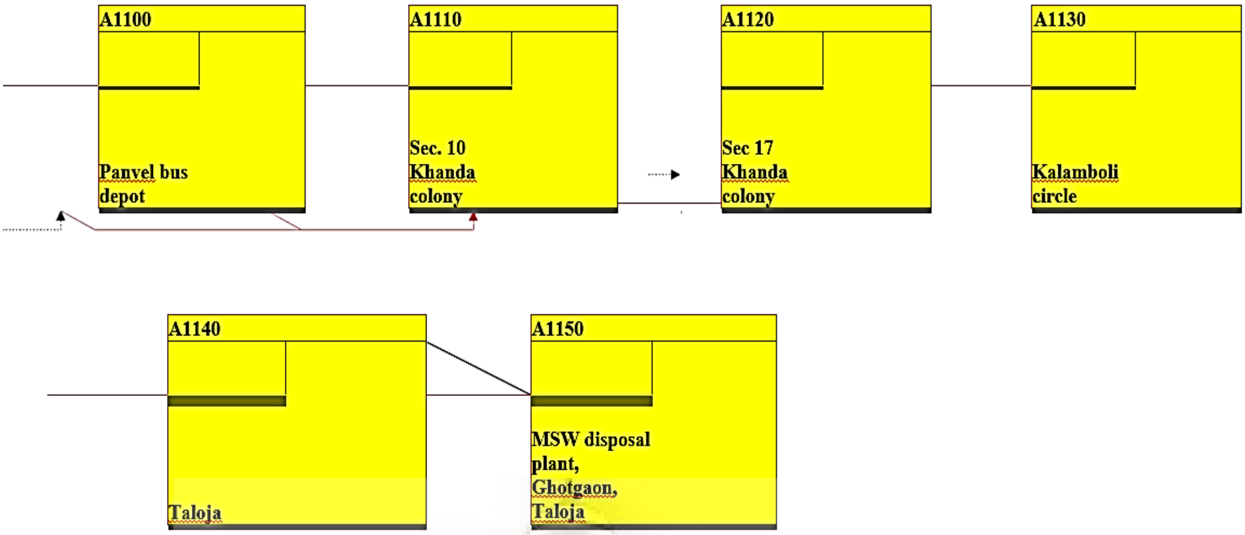

Figure 5.5 Optimum Route selection using PRIMAVERA software

Such that above Fig. 5.5 shows the optimum route using software Primavera. Which is (Panvel bus depot - Sec. 10 Khanda colony - Khanda colony sec. 17 - Kalamboli circle - Taloja - SW disposal plant, Ghotgaon, Taloja).

Fig. 5.6 Gantt chart shows Primavera software analysis report in which the summary of all places on route of Panvel to Ghotgaon, Taloja are mentioned, which helps to determine the optimum route of transportation for carrying municipal solid waste (MSW).

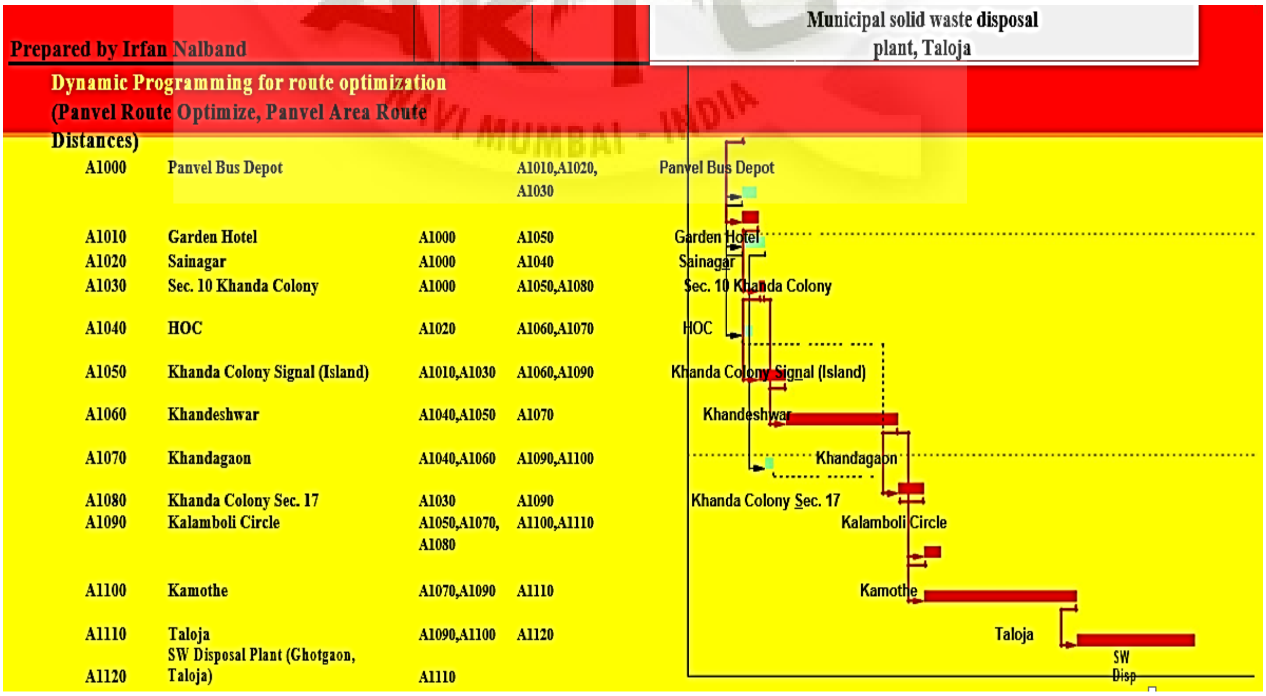

Figure 5.6 Gantt chart, Primavera software analysis report

Fig. 5.6 Gantt chart, Primavera software analysis report shows the highlighted route (Panvel bus depot - Sec. 10 Khanda colony - Khanda colony sec. 17 - Kalamboli circle - Taloja - SW disposal plant, Ghotgaon, Taloja) is an optimum route selected which saves distance and time of transportation as well as ultimately leads to save the cost of transportation of municipal solid waste (MSW).

5.9 Assignment of proper disposal method for MSW

Municipal solid waste is mainly three types are as follows:

1. Organic waste.
2. Inorganic non-combustible waste.
3. Inorganic combustible waste.

Whereas, M_1, M_2, M_3 are the methods of disposal of MSW.

M_1 = Aerobic composting method (Bangalore method)

M_2 = Landfilling method

M_3 = Incineration method

Table 5.9 shows processing time required for different types of municipal solid waste i.e. (Organic waste, Inorganic non-combustible waste, Inorganic combustible waste) to different methods of disposal.

Table 5.9 Assignment of disposal methods to (Municipal Solid Waste) MSW

Disposal Method	M_1	M_2	M_3
MSW types	**Processing time in days**		
1	90	150	110
2	170	60	240
3	140	80	30

This assignment problem is (No. of rows = No. of columns)

Subtract smallest row element (row operation), From Table 5.9 it can be seen that Organic waste, Inorganic non-combustible waste, Inorganic combustible waste are the types of municipal solid waste (MSW) and composting, landfilling, incineration are the methods used for disposal of municipal solid waste (MSW).

Table 5.10 shows processing time required for different types of municipal solid waste i.e. (Organic waste, Inorganic non-combustible waste, Inorganic combustible waste) to different methods of disposal.

Table 5.10 Assignment of disposal methods to (Municipal Solid Waste) MSW

Disposal Method	M_1	M_2	M_3
MSW types	**Processing time in days**		
1	**0**	60	20
2	110	**0**	180
3	110	50	**0**

From Table 5.10 it can be seen that when minimum value is subtracted from every column it gives optimum period of different wastes which can help to assign proper disposal method for Organic waste, Inorganic non-combustible waste, Inorganic combustible waste.

Table 5.11 shows processing time required for different types of municipal solid waste i.e. (Organic waste, Inorganic non-combustible waste, Inorganic combustible waste) to different methods of disposal.

Table 5.11 Assignment of disposal methods to (Municipal Solid Waste) MSW

Type of MSW	Assigned method of disposal	Processing time in days
1	M_1	90
2	M_2	60
3	M_3	30

It can be seen from Table 5.11 that different types of municipal solid waste like Organic waste, Inorganic non-combustible waste, Inorganic combustible waste are bearing optimum processing period of 90 days, 60 days and 30 days respectively. From which proper disposal method can be assigned to waste as per their characteristics.

Table 5.12 shows different types of municipal solid waste to assigned different methods of disposal.

Table 5.12 MSW (Municipal Solid Waste) assigned to disposal methods

Type of MSW	Assigned method of disposal
Organic waste	Aerobic composting (Bangalore method)
Inorganic non -combustible waste	Landfilling method
Inorganic combustible waste	Incineration method

As shown in above Table 5.12 disposal methods viz. Aerobic composting, Landfilling, Incineration are assigned to Organic waste, Inorganic non-combustible waste, Inorganic combustible waste as per their characteristics so that generate revenue from waste and it will be eco-friendly disposal of waste.

5.10 Comparison between designed plant and CIDCO plant

Table 5.13 shows Comparison between designed plant and visited CIDCO plant for disposal of solid waste. Comparison of the salient features are as follows:

Table 5.13 Comparative statement

Sr. No.	Description	Designed plant	CIDCO plant
1	Total area of plant	12 Hectors	14 Hectors
2	Area of landfill	4.54 hectors	5.5 hectors
3	Expected life of landfill	25 years	15.5 years
4	Capacity of landfill	230000 MT/year	365000 MT/year
5	No. Of landfill cells	5 Nos	5 Nos
6	Method of treatment	Aerobic composting	Aerobic composting
7	Weight bridge	40 MT	40 MT capacity
8	Platform for composting	1.72 Hectors	1.3 Hectors
9	Compost plant capacity	87 MT/shift	65 MT/ shift
10	Leachate pond	25 m x 25 m	25m x 25 m

Table 5.13 shows salient features of the Taloja dumping ground where all collected MSW is disposed. CIDCO has proposed further expansion and development of plant for next 15.5 years. With comparison to that, proposed designed plants features are proposed here on the basis of detail calculations shown in articles 5.3-5.5. The comparative study shows that total area of proposed plant is 12 Hector for 25 years duration while CIDCO plant is 14 Hector for 15.5 years duration. Area available for landfilling in proposed plant is 4.54 Hector while in CIDCO plant it is 5.5 Hector, means proposed plant is more feasible than CIDCO plant. Composting capacity for proposed plant is 87 MT/shift while for CIDCO plant it is 65 MT/ shift, such as proposed plant has more capacity of composting compared to the CIDCO plant.

5.11 Summary

Optimum route saves distance and time of transportation which ultimately leads to save the cost and time of transportation of collected municipal solid waste (MSW). Aerobic composting, Landfilling, Incineration are assigned to Organic waste, Inorganic non- combustible waste, Inorganic combustible waste as per their characteristics so that generate revenue from waste and it will be eco-friendly disposal of waste.

Chapter 6

Summary and Conclusions

6.1 Summary

Such that aerobic composting, landfilling, incineration these methods can be used after proper segregation of MSW as per their physical and chemical characteristics. Manure can be used as a good organic fertilizer for agriculture which can also help to raise the revenue. This management for disposal of municipal solid waste is ecofriendly and saves land required for dumping yard and also would have smooth in operation for next 3 decades population.

6.2 Conclusion

From the above study following conclusions are derived:

1. CIDCO planning is for 15.5 years from 2017 onwards and here we have introduced planning is for 25 years from 2017 onwards.
2. Quantity of solid waste will generate after 3 decades, in year 2041 for Panvel area population 619.82 MT/D

3. Maximum landfilling facility even after 25 years later is 230000 MT/ year, whereas CIDCO has proposed landfilling facility 365000 MT/ year and that is up to 15.5 years from current year 2017. Which is unnecessary overburden on plant and not feasible also.
4. Optimum route is selected for the transportation of vehicles which carrying waste from Panvel area to Taloja dumping ground.
5. According to characteristics of solid waste different methods are assigned to different sort of solid waste.
6. Area of landfilling required for next 25 years is 4.54 Hectors and the same proposed by CIDCO for next 15.5 years is 5.5 Hectors. Which is wasting of land and uneconomical.
7. Platform for composting proposed by CIDCO is 1.3 Hectors which is increasing unnecessary burden on landfilling. Increasing composting is necessary to overcome on this situation. So, platform of composting is suggested 1.72 Hectors.
8. Capacity of composting is 87 MT/SHIFT for 1.72 Hectors composting area and the same proposed by CIDCO is 65 MT/ SHIFT for 1.3 Hectors composting area.
9. The population of Panvel area after 3 decades in year 2041 will be about 1721730 people which achieves the objective set earlier.
10. Existing method for disposal of solid waste is landfilling and then covering the waste from top and the suggested methods for disposal MSW are segregation then composting, incineration and landfilling as per characteristic of waste. This helps to save land pollution and wastage of land which achieves the objective set earlier.
11. An optimum route selected which saves distance and time of transportation as well as ultimately leads to save the cost of transportation of municipal solid waste (MSW) which achieves the objective set earlier.

6.3 Future scope of work

The present investigation was confined management and planning for disposal of solid waste in Panvel area. This investigation can be extended in future to the following aspects:

1. Leachate management system
2. Leachate circulation system
3. Leachate treatment and crop irrigation

REFERENCES

[1]. Asnani, P., (2004), "Solid waste management", *Centre for Environmental Planning and Technology*, volume 20, part 8, ISSN 979-991, (pp- 1, 2), Ahmedabad, Government of India.

[2]. Cristen, C., (2017), "Solid waste management and recycling in Maryland", *Department of Legislative Services Office of Policy Analysis*, volume 11, ISSN 2779-221, (pp-3,4) Annapolis, Maryland - 21401

[3]. Das, S., (2013), "Municipal Solid Waste Characteristics and Management in Kolkata, India" *International Journal of Emerging Technology and Advanced Engineering*, Volume 3, ISSN 2250-2459, ISO 9001:2008, (pp- 147-150)

[4]. Douti, N., (2017), "Solid Waste Management Challenges in Urban Areas of Ghana: A Case Study of Bawku Municipality", *international Journal of Geo-sciences*, volume 8, ISSN: 2156-8359, (pp- 494-513)

[5]. Francis, R. C., (2013), "Solid Waste Management and Characteristics in Lucknow, Uttar Pradesh, India" *International Journal of Scientific & Engineering Research*, Volume 4, Issue 11, ISSN 2229-5518, (pp- 13-17)

[6]. Gautam, S., Pandey, A., Bundela, P., (2010), "Composting of Municipal Solid Waste of Jabalpur City", *Global Journal of Environmental Research*, volume 17, ISSN 1990-925X, IDOSI Publications, (pp- 47-53)

[7]. Joshi, M., Patil, S., Mourya, K., (2013), "Solid Waste Management on Dumping Ground in Mumbai Region – A Study", *International conference on Green Computing and Technology*, Volume 1, ISSN 0975-8887, (pp- 20-22)

[8]. Kanfound, S., (2017), "Municipal Solid Waste Management in Constantine, Algeria" *Journal of Geoscience and Environment Protection*, volume 5, ISSN: 2327-4336, (pp-85-93)

[9]. Kumar, S., (2017), "Guidelines on Odour Monitoring & Management in Urban Municipal Solid Waste (MSW) Landfill Site" *central pollution control board*, Parivesh Bhawan, East Arjun Nagar, Delhi – 11003, (pp- 33-47)

[10]. Mukherjee, N., (2015), "Understanding our civic issues, SWM in Mumbai" *Series Editor journal of Bombay community public trust,* editor copy (pp- 03-06).

[11]. Rana, R., Gupta, A., (2014), "Solid Waste Management in Chandigarh – A Case Study" *Journal of Civil Engineering and Environmental Technology*, Volume 1, Print ISSN: 2349-8404; Online ISSN: 2349-879X; Number 4; August, 2014, (pp- 68-70).

[12]. Rout, C., Sharma, A., (2010), "Disposal of Municipal solid waste", *International journal of environmental sciences*, Volume 4, ISSN 0976 – 4402, (pp- 07-11).

[13]. Sasikumar, S., Gopikrishnan, K., (2014), "Solid Waste Management", *International Journal of Research in Socialsciences and Humanities*, volume 17, ISSN: 2249-4642, (pp- 53-66).

[14]. Shah, O., (2006), "Sustainable Waste Processing in Mumbai", *Implementation of Sustainable Technology, International Journal*, volume 22, ISSN 2139-4938, (pp- 08-11).

[15]. Shirke, A., (2009), "State of Environment Report- Chandigarh", *Ministry of Environment and Forests*, Government of India, (pp- 01-04).

[16]. Sinha, B., (2016), "Ministry of Environment, Forest and Climate change Notification", *The Gazette of India*, Part II, Section 3,Sub-section (ii), New Delhi, (pp- 13-17).

[17]. Tchobanoglous G., (2014), "Solid waste management" *Integrated Solid Waste Management- Engineering Principles and Management Issues*, edition 2,New Delhi, India, MCGRAW HILL, (pp- 114-119).

[18]. Vaidya, R., (2002), "Solid Waste Degradation, Compaction and Water Holding Capacity" *Virginia State University, Environmental engineering department*, volume 21, ISSN 0556 – 7602, Blacksburg, Virginia, (pp- 31-34).

[19]. Varma, A., (2007), "Status of munic Executive Director, pal solid waste generation in kerala and their characteristics" *Suchitwa Mission Local Self Government Department Thiruvananthapuram,* Executive Director, volume 1, ISSN 0695- 1014, (pp- 01-03).

[20]. Yadav, B., (2017), "Recent Scenario of Solid Waste Management in India", *World Scientific News*, WSN 66 (2017), EISSN 2392 – 2192, (pp- 56-74).

LIST OF PUBLICATIONS

[1]. "Management and planning for disposal of solid waste in Panvel area", NICMAR, Pune, **International conference (22nd Oct. 2016)**

ACKNOWLEDGEMENT

I consider myself lucky to work under guidance of such talented and experienced people who guided me all through the completion of my dissertation.

I express my deep sense of gratitude to my guide **Dr. R. B. Magar**, Professor and Head of Civil Engineering Department for his valuable time and aspiring guidance for my project work, I also thank **Prof. Dhaval Shah** and **Mr. Syed Ilyas Qadri** for his support and guidance.

I am grateful to **Dr. Abdul Razzak Honnutagi**, Director for his support and co-operation and for allowing me to pursue my Master's Degree Programme besides permitting me to use the laboratory infrastructure of the Institute.

I am thankful to my course coordinator **Prof. Fauwaz Parkar,** for his support at various stages. I would also like to thank **Mr. Afroz Khan**, for his valuable help in completion of my work.

Last but not the least my thanks also goes to other staff members of Civil Engineering Department, Anjuman-I-Islam's Kalsekar Technical Campus, Panvel, library staff for their assistance useful views and tips.

I also take this opportunity to thank my beloved parents and brothers for their support and encouragement at every stage of my life.