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ROUTE OPTIMIZATION FOR MUNICIPAL SOLID WASTE DISPOSAL SITES IN GONDIA, MAHARASHTRA STATE, INDIA

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Abstract: Municipal solid waste is mainly generated due to urbanization and development and has emerged as a severe threat to environment. Inappropriate disposal of municipal solid waste may harmfully affect environment and human health. Municipal solid waste management is desired for the solution of the problem of solid waste disposal pertaining to protection of the environment and conservation of natural resources. Gondia Municipal Council's solid waste management in this study involves the collection of waste from various locations to some common point known as waste collection centre. The collected waste is then transported to nearest available facilities namely landfill site and disposal site. The main aim of this study is to exhibit the route optimization model for fixing collection centers, considering capacity of automobile as 3 tons being used for assortment and the distance between optimized collection centers and disposal facilities of solid waste with potential routes. The least distance locations of waste centers may be utilized by the municipal solid waste management for cost effectiveness with an objective of sustainable development of city. The outcome of the study reveals effective reduction of 22255 meters of distance coved per day by the automobile.

Keywords: Automobile Routing Problem (ARP), Gondia Municipal Council (GMC), Automobile Routing Model (ARM), Municipal Solid Waste (MSW).

INTRODUCTION

Urbanization has brought forth several maladies and suffering to human kind, besides bringing economic and cultural development in its fold. Due to pressure of urbanization most of the cities are growing fast and sometimes they develop beyond the planned limits [11]. The problem of municipal solid waste management varies in enormity in different regions, nations and cities of the world. The chief pouring forces after waste generation are population, utilization, prosperity and technology. Many cities in developing nations face grim problems in managing their municipal solid waste. In the developing nation like India, the stronger pouring force for increasing waste amount is the high rate of urban population growth [1]. Whereas urbanization has helped improve the economic and social situation of developing countries, the major confront being the appearance of environmental problems, among these problems municipal solid waste management is one of them [14]. India is the world's second uppermost populated nation with population exceeding 1.21 billion. Hurried industrialization, urbanization and population explosion has lead to immigration of people from rural sector to urban. Due to migration to the urban area by the rural population, the present level of service in many urban areas is so low that there is a threat to the public health in particular and the environmental quality in general [16-5]. The Municipal Councils and Municipal Corporations are responsible for providing Municipal Solid Waste Management services in the urban areas. In most of the urban areas, insufficient funds, use of outdated or inept technologies, lack of public awareness and training, and improper infrastructure have resulted in a poor state of municipal solid wastes management [14-15-8-9]. The activities associated with the management of municipal solid wastes from the point of generation to final disposal can be grouped into the six functional elements: (a) waste generation; (b) waste handling and sorting, storage, and processing at the source; (c) collection; (d) sorting, processing and transformation; (e) transfer and transport; and (f) finally disposal of harmless residues [4-6-17]. Therefore, the present study aims to establish the quantitative and qualitative distinctiveness of municipal solid waste management along with fundamental information, which is suitable for municipal solid waste management for Gondia city.

METHODOLOGY

The Vehicle Routing Problem (VRP) is one of the mainly tough combinatorial optimization tasks. This problem consists in designing the optimal set of routes for fleet of vehicles in order to dish up a given set of customers. The interest in VRP is aggravated by its practical application as well as by its substantial complexity [7]. A typical vehicle routing problem

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includes simultaneously determining the routes for specified number of vehicles from a central supply depot to a number of municipal wards and returning to the depot without exceeding the capacity constraints of each vehicle [3]. Route optimization model may be described as finding the minimum distance. Each node represents a municipal sector in this work. It is effectively the routing of vehicles from a central storage area for the assortment of waste from sub locations. The problem is solved under the following constraints [10].

A. Each municipal sector is visited only once by a single motor vehicle;
B. Each motor vehicle must start and end its route at the storage area and
C. Total demand serviced by each motor vehicle cannot exceed its capacity.

Objective functions:

Minimize

$$\sum_i \sum_j C_{ij} X_{ij} - \sum_j V_j Y_j \qquad (1)$$

X_{ij} = units of carried from sub-location i to sub-location j

C_{ij}= cost of switching from sub-location i to sub-location j

Y_j = 1 if sub-location j is visited, 0 otherwise.

Y_j = the value of visiting sub-location j,

$\sum_i V_i Y_j$ = the profit or benefit by visiting location j.

Subject to

Each sub-location, j, must be visited once for j > 1:

$$\sum_j C_{ij} = 1 \qquad (2)$$

Each sub-location i > 1, must be exited once:

$$\sum_i X_{ij} = 1 \qquad (3)$$

No sub tours:

$$\sum_{i,j \in S} X_{ij} \leq |S| - 1, \qquad (4)$$

No overloads: For each set of municipal sectors T, including 1, which represent more than a truck load:

$$\sum_{i,j \in T} X_{ij} \leq |T| - k, \qquad (5)$$

Where k = minimum number of municipal sectors that must be dropped from T to decrease it to one load.

We have measured vj = 0; and hence

$$\sum_j V_i Y_j = 0$$

DESCRIPTIVE FUNCTION OF THE OPTIMIZATION MODEL FOR GONDIA MUNICIPAL COUNCIL

Gondia urban complex has been chosen for the present study. Gondia urban complex is urban agglomeration of Tirora, Amgaon, Goregaon, Salekasa, and some other small towns. Gondia is one of the fast growing cities of central India. The Gondia Municipal Council (GMC) governs solid waste management in Gondia town. In order to demonstrate the expediency of the optimization models in real field situation, data for the performance evaluation are taken according to the situation in Gondia town as shown in Fig: 1.

Fig.1: Location Map of GMC Source: gondia.nic.in/

GMC is situated on the central plateau with its cardinal points 21° 27'26"North latitude and 80° 12' 53"East longitude with an altitude of 308.45 Meters above MSL. GMC covers an area of 24 Sq Km. According to census data of 2001 the population was 0.12 million and percentage of literacy rate was 67.67 but as on 2013 the population of GMC is approximately around 0.16 million. In 2001 the number of households was 27702 and as on 2013 the number of households is 32896[13].

The entire operation of solid waste management system is performed under four heads, namely, cleaning, collection, transportation and disposal. The entire city is divided into 10 Municipal Sectors [11]. For the purpose of solid waste management, the Gondia city is divided into two zones by the Howrah-Mumbai railways track i.e. North and South as shown in Fig. 2. Total land area of GMC 1808 hectors is included in the municipal limit. Till the first revision of development plan 546 hectors land was developed. After 1st revision of development plan total development area is only 717.45 hectors out of which the area under residential use is 308 hectors as shown in Fig. 2. It is due to the decreased rate of population increment [12]. The Residential development is nearly equal on either sides of the city. 155 hectors is under roads & 91.25 hectors land is under railway line.

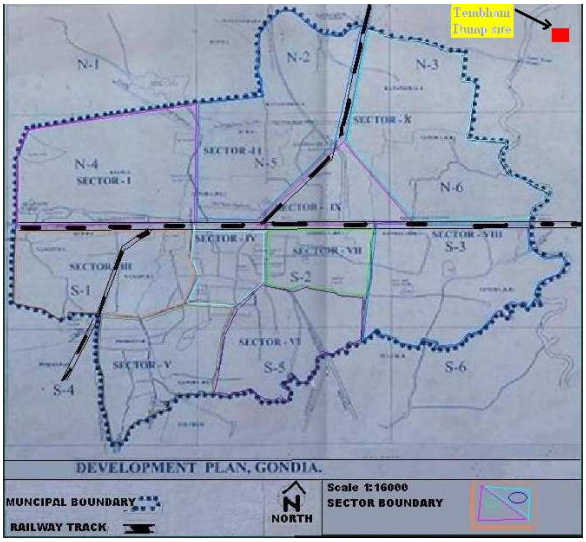

Fig.2: Shows Boundary Map of Gondia Municipal City (after Pandey, 2012).

In the present study two zones namely north and south are considered to demonstrate the use of vehicle route model for minimization of distance for collection of waste. The details of other useful components of MSW management of Gondia Municipal Council are shown in Table 1. At the moment city does not have existing waste management component, so values of some of the parameters are subjective.

Table.1: Details of MSWM components.

MSWM Components	Location
Landfill	South Zone, Gausala Road, Marghat Raod. North Zone, Sardar Patel Colony, opposite NMD College & Old TB Hospital.
Storage Area	Village Temni 16 km from City.

MSW CHARACTERIZATION

The population data for the study area is obtained from the GMC for the census year 1991 to 2001 to calculate the population projections for each sector. The population projections are done by various methods being used by GMC. In the Sectional Development Plan, population for the year 1991 and 2001 was estimated to 1, 39,000 and 1, 85,000 respectively. However, the actual population recorded by census is 1, 09,470 in 1991 and 1, 20,878 in 2001. The % rise in the population in last two decades is 9% and 10.42% in the year 1991 and 2001 respectively. This is very low as compared to % of growth in the previous eight decades. This downward trend of % growth is due to following reasons [12].

- Many rice mills established in the past are shifted in the territorial area outside the municipal council limit. Most of the rice mills are closed due to shifting in the outer area.
- In the last two decades educational institutes like Engineering College, Homoeopathic college, I.T.I. and Polytechnic etc. have come up in the year by rural areas, so as administrative buildings, Zillah Parisad, Police Headquarters and many such offices and business activities have come up in the rural areas outside the municipal council boundary in Mouza-Fulchur and nearby Mouza Karanja which is situated on Goregaon and Amgaon state highway.
- Due to fast development in the outside area, many residential colonies are come up in that area .In that contest more and more population is tend to settle down there. This ultimately checked the population growth within the town itself .The another reason for fast development is due to fact that the land in the municipal council area are very costly as compared to the land in outside area and the properties in the GMC area are heavily taxed[12].
- Due to social awareness and rise in education percent, small size family concept is developed which ultimately checked the population growth during last two decades in the town.

In the above reference the % raises, that of 9% to 10% in the past two decades that is in the year 1991 and 2001 reflect the natural growth of the population. However since Gondia is declared as district headquarters from 1.5.1999. Due to change in status of the town many more government offices and establishment are come in the city and outside the city limit thereby resulting slight change in % growth of population .Considering the average rise for the last two decades and also considering the change in status of the town ,overall average % rise in population per decade could be 20% flat which seems to be reasonable while accessing the population for the year 2011 and 2021 .Considering the flat percent rise of 20% per decade population for the year is worked out as below, which is nearly matching with 2011 census [12].

1) For year 2011- 120878*1.20=145054 souls say 145100 souls.
2) For year 2021-145054*1.20=174064 souls say 174100 souls.
3) For year 2031-174064*1.20=208877 souls say 208900 souls.

Estimate by Various formulas:

The population census data of last 5 decades (1951-2001) is taken into consideration to estimate the projected population [12]. The population worked out by various methods for the year 2011 & 2021 is shown in the Table 2

Table.2: Showing Projected Population.

Method/Formulas used		Adopting growth rate of 1981-91		Adopting Growth rate of 1991-01	
	2001	2011	2021	2011	2021
Public health formula	119322	130061	141766	133473	147381
Arithmetical progression	127666	145862	164058	137018	153158
Geometrical progression	144982	192014	254303	147060	178913
Graphical	132000	144000	151000	130000	137000

It is seen from the Table 2 that the population figure worked out by Geometrical progression method is highest as compared to other three methods. These are as shown in theTable.3.

Table.3: Showing Growth Rate Method Projected Population.

	Year	2011	2021
A	Adopting growth rate of 1981-1991	192014	254303
B	Adopting growth rate of 1991-2001	147060	178913

Decadal % rise of the population in 1951 is as high as 80.54% which rapidly comes down to 28.76% in the decade 1981- However in the last two decades i.e.in the year 1991 & 2001 average % rise per decade is steady between 9% to 10% [12].

As discussed above population worked out by considering flat rate of 20% and geometric progression method (Adopting growth rate of 1991-2001) is nearly co-ordinate, with each other as shown in the Table 4.

Table.4: Showing Flat Rate & Geometric Progression Method Projected Population.

	Year	2011	2021
A.	Flat rate of 20%	145100	174100
B	Geometrical projection	147060	178913

Sector wise distribution of population:

For planning at micro level, area under GMC jurisdiction is divided into 10 sectors. Above mentioned projected population is required to be distributed sector wise, based on population in existence within those sectors as per the Census of 2001, projected population on this basis per sector for the year 2015 & 2025 is worked out as shown in the Table 5 [12].

Table.5: Showing Distribution and Projected Population.

Sector No.	1	2	3	4	5	6	7	8	9	10	Total
Year 2015	25277	18385	25120	8431	13847	9012	14741	18934	7348	15904	157000
Year 2025	30600	22250	30400	10200	16750	10900	17850	22900	8900	19250	190000

At first, the population with 10% floating population is estimated for the city as well as in each sector. The estimated population combined with the waste generation capacity per capita is used to find out the total wastes generated in each sector.

Municipal solid waste, usually known as rubbish or garbage, is made up of things we commonly dispose off by throwing away. This household type of waste ranges from our package wrappings, food and scraps. It does not contain industrial, medical, hazardous, or construction waste. Despite sustained improvements in waste reduction, household waste remains a constant concern because trends indicate that the overall tonnage we create continues to increase. In the year 1991 the total MSW of GMC was around 12786 Tonnages, where as in the year of 2001 MSW of GMC was found 14118.5 Tonnages. Hence it is observed the MSW of GMC has increased to the tune of 90 % in ten years. The average generation rate of individual MSW at GMC has remained relatively constant since the 2001 at 0.320 Kg. per person per day [11]. Sources of MSW include both residential and commercial locations. The estimated residential waste is projected in between 55 to 60 % of total MSW generation. Waste from schools and commercial locations, such as hospitals and business activities constitute 35 to 40 % of MSW [11].

The waste specified generated in a particular sector is as termed as waste sources. The capacity of automobile starts at a first waste source as a common collection point and visit to nearest waste source and pick up the waste, when capacity of automobile is not full, it needs to go to the closest available waste source. When an automobile is filled to its capacity, it needs to return to the first waste source. In the present study 8 sectors out of 10 sectors are considered to demonstrate the use of means of automobile transportation route model for minimization of distance for collection of waste. The sector IV from North zone and Sector IX from South zone have not been fully considered to demonstrate the use of means of automobile transportation route model, since some areas of these sectors fall under rural administration. The details of other useful

components of MSW management of GMC are shown in Table 1.

MSW CHARACTERIZATION FOR 10 SECTORS

In this section, ten sectors are covered having population of 145100 which generate 46.432 tons of waste per day. The north zone includes sector I, II, IX & X where as reaming sectors are included in south zone. Allocation of the average magnitude and type of projected waste generated by 10 sectors in the year 2015 and 2025 are shown in Table 6.

Table.6: Projected MSW Generated by Sectors in the Year 2015 and 2025.

Sector No.	I	II	III	IV	V	VI	VII	VIII	IX	X	Total
Year 2015 Projected Population	25277	18385	25120	8431	13847	9012	14741	18934	7348	15904	157000
Projected MSW in Tons. @0.320Kg/ Person.	2952	2147	2934	985	1617	1053	1722	2211	858	1763	18242
Year 2025 Projected Population	30600	22250	30400	10200	16750	10900	17850	22900	8900	19250	190000
Projected MSW in Tons. @0.320Kg/ Person.	3574	2599	3551	1191	1956	1273	2085	2675	1040	2248	22187

RESULTS AND DSICUSSIONS

Automobile Routing Model (ARM) represented by equation 1 to 5 is solved to obtain collection centers also known as waste centers in each sector. The ideal route calculated by the model reflects minimum travel distance for collection of solid waste. The results indicate that the routes calculated by the route optimization model fairly represent the reality. The automobile routing model is effective for modest-sized ten sectors. All sectors in general, generate waste more than the capacity of motor vehicle used that is 3 tons. Therefore, each motor vehicle needs to visit at least three times in each sector, first for completely filled motor vehicle to transfer directly to common collection point and then for remaining waste. The automobile routing model is used to find out the optimized route to be followed by motor vehicles to collect the waste less than full capacity of motor vehicle at all the ten sectors. The combined distance covered by automobile is shown in Table 7 for north zone. Each source point of the waste collection site turn by turn is treated as collection point for the whole sector hence it is treated as starting point for each model run. The waste generated at starting sector is assumed to zero and distance travelled is also zero.

Table.7: The total distance travelled at different sectors in North Zone of GMC using optimization model.

Sector	Area in Sq. Km.	Distance covered Fully loaded Automobile per day in Meters	Optimized Distance in Meters by Automobile Routing Model	The Distance in Meters from the waste source to Dump Site	Total Distance in Meters
Sector I	2.5319	4630	3400	10900	18930
Sector II	1.9414	4780	2150	8205	15135
Sector IX	0.4603	4110	3290	11340	18810
Sector X	4.2932	4850	3140	7600	15590

Considering sector II (N5) of North zone as shown in Fig.3 as starting point which also acts as a collection point, all the waste from different sectors are collected in sector II. The total distance covered by the automobile is 7050 Mts. for collection of waste of amount of 21.149 tons. It is the sum of optimized distance by automobile routing model that is 2150 Mts. and summation of distances between all sectors that is 4780 Mts. and final distance covered to transfer to present dumping site at Tembhni is 8205 Mts. Similarly, different sectors of this zone are treated as a starting point alternately in each model run and the optimal results are shown in Table 7. It is clear from the Table 7 that sector IX (4110Mts.) is minimum distance of sectors which represents optimized waste source location (collection point).

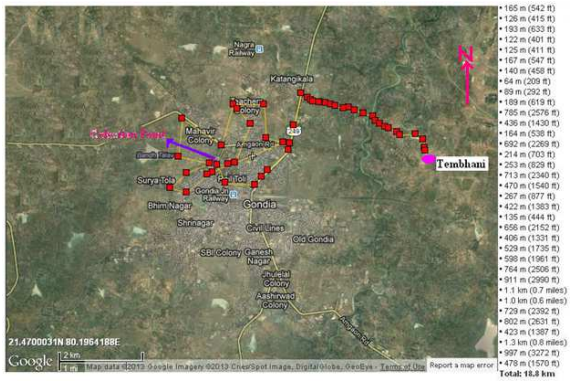

Fig. 3: Showing Optimized Route of North Zone of Gondia Municipal Council (Source: google earth.com)

South zone consists of 6 sectors. Similarly, considering sector VI (S2) of South zone as shown in Fig.4 as starting point which also acts as a collection point. The optimal results are shown in Table 8. It is clear from the Table 8 that Sector VI is minimum distance (12900Mts.) as shown in Fig. 4 traveled between sectors which represent optimized waste source location for South zone.

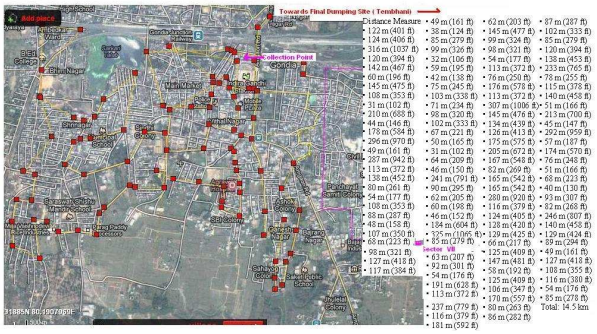

Fig.4: Showing Optimized Route of South zone of Gondia Municipal Council (Source: google earth.com)

A separate optimized route for sector VII belong to south zone of GMC has been proposed on account of its isolated geographical location as shown in Fig. 5.

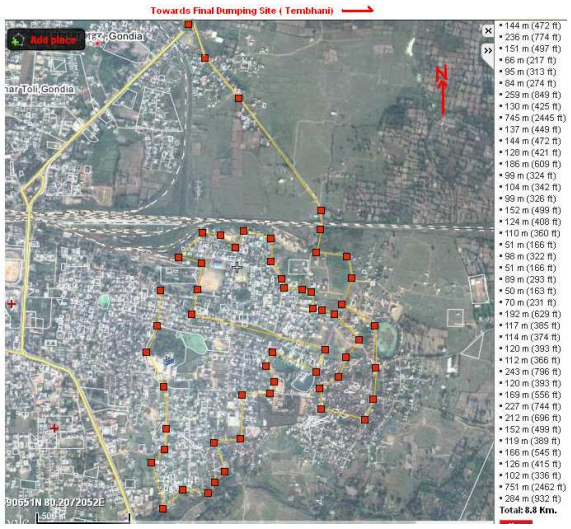

Fig. 5: Showing Optimized Route of Sector VII of South Zone of Gondia Municipal Council (Source: google earth.com).

The total sum of distance covered by fully loaded automobile is 61380 Meters of or both sectors of GMC while optimized distance covered by ARM is 39125 Meters, which is less by 22255 Meters per day.

Table.8: The total distance travelled at different sectors in South Zone of GMC using optimization model.

Sector	Area in Sq.Km.	Distance Covered Fully Loaded Automobile per day in Meters	Optimized Distance in Meters by Automobile Routing Model	The Distance in Meters from the waste source to Dump Site	Total Distance in Meters
Sector III	1.9314	6800	4685	14500	25985
Sector IV	0.7305	5900	3800	13200	22900
Sector V	1.5111	6520	3900	14300	24720
Sector VI	1.0608	6670	4560	12900	24130
Sector VII	1.2809	5670	3500	8900	18070
Sector VIII	2.3518	11450	6700	11200	29350

CONCLUSION

The explicatory function of optimization model shows that automobile routing model presented in this work can minimize 22255 Meters of length per day covered by fully loaded automobile is suitable for MSW management of Gondia municipal council. In this manner the methodology accessible here, reveals a cost effective widespread scaffold of MSW management for sustainable development.

REFERENCES

1. Akolkar, AB, Status of Solid Waste Management in India, Implementation Status of Municipal Solid Wastes, Management and Handling Rules 2000, Central Pollution Control Board, New Delhi, 20-79, 2005.
2. Cheng, S, Chan, CW, Huang, GH, An integrated multi criteria decision analysis and inexact mixed integer linear programming approach for solid waste management Eng. Appl. Artificial. Intelligence, 16 (5-6), 543-554, 2003.
3. Clarke, G and Wright, JW, Scheduling of Vehicles from a Central Depot to a Number of Delivery Points, Operations Research, 12(4), 568-581, 1964.
4. CPCB. Status of Municipal Solid Waste Generation, Collection Treatment, and Disposal in Class 1 Cities, Central Pollution Control Board, Ministry of Environment and Forests, Government of India, New Delhi, 67-90, 1999.
5. CPCB, Status of Solid Waste Generation, Collection, Treatment and Disposal in Metrocities, Series: CUPS/46/1999–200, 2000
6. CPHEEO, (Central Public Health and Environment Engineering Organization), 'Manual on solid waste management' Ministry of Urban Development, Government of India, 2000.
7. Lenstra JK., Kan Rinnooy, AHG, Complexity of vehicle routing and scheduling problems, Networks, 11, 221-227., 1981.
8. Ministry of Environment and Forests (MoEF), The Gazette of India. Municipal Solid Waste (Management and Handling) Rules, New Delhi, India, 2000.
9. NEERI, Strategy Paper on SWM in India, National Environmental Engineering Research Institute, Nagpur, 1995.
10. Racal, N, Singh RM, Vishay RC, Waste Characterization and Route Optimization for Solid Wastes in Urban, Volume 04, No 06 SPL, 438-442, 2011.
11. Pandey, D, Selection of Prospective Waste Disposal Sites for Gondia Municipal Council of Maharashtra, India. Int. J. LifeSc. Bt & Pharm. Res. Vol. 1, No. 3, July, 174-181, 2012.
12. Pandey, D, Land Use and Land Cover Planning of Gondia Municipal City, Maharashtra State, India Using Remote Sensing & GIS Techniques, Int. J. LifeSc. Bt & Pharm. Res. Vol. 1, No. 4, October, 46-64, 2012.
13. Pandey, D, Surface Water Quality with Painstaking Human Impacts - A Case Sstudy of the Wainganga River, Bhandara, Maharashtra, India, Int. J. Biossays, Vol 2, No 01, 272-277,2013.
14. Shekdar, AV, Krshnawamy, KN, Tikekar, VG and Bhide, AD. Indian urban solid waste management systems – jaded systems in need of resource augmentation, Journal of Waste Management, 12 (4), 379–387, 1992.
15. Siddiqui, MZ, Everett, JW, Vieux, BE, Landfill siting using geographic information systems: a demonstration, J. Environ. Eng., 122 (6): 515-523, 1996.
16. Supreme Court "SC" "Report of the Supreme Court Appointed Committee on Solid Waste Management in Class I Cities in India", Supreme Court of India, New Delhi, 1999.
17. www.urbanindia.nic.in/publicinfo/swm/chap2.pdf (accessed 23/01/2013).

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