CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

The literature pertaining to the following areas were reviewed and presented in this chapter. The review areas include:

- Municipal Solid Waste Management
- Vehicle Routing Problem
- GIS applications in municipal services, transportation
- GA applications in transportation to find optimal routes.

Optimization models and related methods have been widely applied to different issues in solid waste management, including optimization of collection routes (Ramachandra et al 2003), suitable location of waste bins, site selection of waste disposal (Syed Mahmood Anwar 2005, Muthiah et al 1996), site selection of transfer stations (Ramachandra et al 2003, Clarke et al 2005), and selection of networks of treatment, transport, and disposal activities for hazardous waste.

Optimal routing is arrived at as a micro level study of macro routing, in such a way that the waste will be collected within a specific time period on minimum travel time concept. The corresponding micro routing for locations in each zone is left as it is, considering the experience of collection workers.
2.2 MUNICIPAL SOLID WASTE MANAGEMENT

Municipal Solid Waste Management (MSWM) system in India is gaining more importance mainly because of increasing urban population and public awareness towards cleanliness. There is a wide difference in the waste composition and the techno-socio-economic condition, when compared with the conditions in the developed countries. This necessitates the development of appropriate technology for municipal solid waste management in India. There is also a need for a country-specific national policy, and a legal and revenue structure for MSWM (Shekdar 1999).

Review articles on basic components of SWM are waste generations, storage, collection, transport, waste bin types and location, waste processing, recovery and disposal outlining the need for quantification. Both in the past and in the present, inadequate attention has been paid to engineered disposal and its practice. Waste is simply dumped on the ground, open to the atmosphere as followed elsewhere without appropriate treatment and resource recovery practice. Different types of waste bins namely cylindrical concrete bins, small wooden bins, cubic concrete bins, masonry hut bins, stone bins, cubic plastic bin, stainless steel bins (Ramachandra et al 2003, Alexandre Magrinho 2006, Shekdar 1999) are in common use in corporation areas.

Efficient routing and en-routing of solid waste collection vehicles can decrease the costs by reducing the labor expended on waste collection. Routing procedures usually consists of two separate components: Micro routing and Macro routing (EPA 1995).

Macro routing, also referred to as route balancing, consists of dividing the total collection area into routes sized so that they represent one day’s collection for one crew. The size of each route depends on the quantity of waste collected per stop, distance between stops, loading time, and traffic conditions.
Micro routing can define the specific route that the collection vehicle should follow. The method selected for micro routing must be simple enough to use for route balancing, when system changes occur or to respond to seasonal variations in waste generation rates.

In order to improve the current solid waste management services, it is essential to explore the various constraints or issues such as community participation, human resource development, promoting GIS-GPS (Global Positioning System) systems to obtain reliable data on waste and legal mandates.

In India, however, due to the lack of awareness and co-operation from citizens, the community bins often have a large quantity of waste littered around with only a meager quantity deposited inside. Due to unsanitary conditions, the nearby residents object to the location of bins near their premises, thus necessitating their location at public places that are often not the best sites. An approach to assess the satisfaction level with regard to the performance of the solid waste system has been formulated and then tested through a case study. This will provide a crucial feedback to the management on the effectiveness of the existing system and identify areas where restructuring is needed (Raje et al 2001).

The prevailing system in most of the urban centers is yet to emerge out as an organized program. The critical assessment of the prevailing system indicates short comings like irregular removal of solid wastes from collection areas, under utilization of existing resources, degradation of environmental quality, and poorly organized system at high costs. Accordingly, the improvements are proposed addressing the issues like delineation of national policy for waste management, development of appropriate technology, master planning of the system for every town, public participation and awareness, provision of adequate financial resources, and effective legal structure and their enforcement (Shekdar 1999).
In a SWM, maximum amount of finance is allotted for transporting the waste products. Hence it is necessary to identify an optimal route and schedule the transportation vehicles. To assist decision makers in developing optimal scheduling plans (Everett and Modak 1996), a mathematical model is developed and waste management options, for a region, are proposed. This is known as regional-scheduling model. The objective function given by Everett and Modak 1996 is

Minimize  
\[
Z = \sum_{w} \sum_{j} \sum_{a} \sum_{z} \sum_{t} \frac{CTC_{wjazt}}{(1 + r)^t} X_{wjazt} + \sum_{w} \sum_{j} \sum_{a} \sum_{p} \sum_{t} \frac{PC_{wjapt}}{(1 + r)^t} X_{wjapt} + \sum_{w} \sum_{j} \sum_{a} \sum_{c} \sum_{t} \frac{CC_{wjact}}{(1 + r)^t} X_{wjact} 
+ \sum_{w} \sum_{j} \sum_{a} \sum_{l} \sum_{t} \frac{LC_{wjalt}}{(1 + r)^t} X_{wjalt} - \sum_{w} \sum_{j} \sum_{d} \sum_{p} \sum_{t} \frac{REV_{wjdpt}}{(1 + r)^t} D_INV_{wjdpt} 
+ \sum_{w} \sum_{j} \sum_{d} \sum_{c} \sum_{t} \frac{REV_{wjdct}}{(1 + r)^t} X_{wjdct} - \sum_{c} \sum_{t} \frac{REV_{ct}}{(1 + r)^t} TEN_{ct} 
\]

for all \( w,j,a,z,p,c,l,d,t \)

where  
- \( CTC_{wjazt} \) = unit cost of transporting waste type \( w \) under collection option \( j \) in source \( a \) and transporting it to destination \( z \) in year \( t \) (includes collection costs if node \( a \) is a community);  
- \( PC_{wjapt} \) = unit cost of processing waste type \( w \), collected under option \( j \) and transported from source \( a \) to the processing facility \( p \) in year \( t \),  
- \( CC_{wjact} \) = unit cost of incinerating waste type \( w \) in incinerator \( c \) in year \( t \);  
- \( LC_{wjalt} \) = unit cost ($/t) of landfilling waste \( w \) in landfill \( l \) in year \( t \);  
- \( REV_{wjdpt} \) = unit revenue ($/t) for waste type \( w \), diverted under collection option \( j \), using diversion option \( d \) at facility \( p \) in year \( t \);  
- \( REV_{wjdct} \) = unit revenue ($/t) for waste type \( w \); diverted under collection option \( j \), converted to compost at facility \( c \) in year \( t \),  
- \( REV_{ct} \) = unit revenue ($/t) from the sale of energy at facility \( c \) in year \( t \); and \( r \) = discount rate. If \( a \) is a community, \( CTC \) includes the cost of collection as well as transportation.
energy recovery is to be accomplished at a landfill, additional terms must be include in the objective function.

The model is capable of handling multiple communities and landfills, and incorporates the possible implementation of numerous diversion options in a region. The model solutions demonstrate the ability of the model to optimally schedule processing, conversion, and landfill options, and calculate long-term optimal SWM costs for a regional integrated SWM system. The options that are less expensive are scheduled earlier in the planning period. As the capacity of low costs or nearby landfills is depleted, more expensive or distant landfills are opened (Everett and Modak 1996).

Eric Solano et al (2002) presented a comprehensive mathematical model for Integrated Solid Waste Management that accounts for cost, energy, and environmental emissions. This model is formulated as a linear programming model that can be solved to identify an efficient SWM strategy, which is defined by a complete set of unit processes, and the amount of each waste item handled within these unit processes. The variable definitions and model equations are structured especially to avoid non-linearity that would arise typically due to the types of decisions being represented by this model. The modeling approach is described using a small example problem. Illustrations of the use of this model for a more extensive case study are also presented.

A report on lessons from Solid Waste Management projects in India- A historic perspective by Bhide states that the SWM is one of the various areas to be covered in the ‘Ecocity’ program. The central pollution control board has taken up the project under the ‘Ecocity’ program of the Ministry of Environment and Forest as the nodal agency and will execute the project through the concerned state agencies. In this program modern facilities are proposed to be set up in such selected towns where the quantity of MSW is expected to be between 300 and 500 tons per day.
The Jawaharlal Nehru National Urban Renewal Mission (JNNURM) was constituted with an aim to encourage reforms and fast track development of identified cities. According to JNNURM, for a population of 1 to 4 million, 28 cities were identified for granting fund to improve SWM. MC is also granted a sum of Rs.56 crores under JNNURM for innovations (The Hindu and Dinamalar dated 02.07.09).

2.3 VEHICLE ROUTING PROBLEM

A vehicle routing problem can be described as the problem of designing least cost routes from one depot (dumpsite) to a set of geographically scattered points (garbage collection points). The routes must be designed in such a way that each point is visited only once by exactly one vehicle, all routes start and end at the depot, and the total garbage collected at all collection points on one particular route must not exceed the capacity of the collection vehicle. The vehicle routing problem with time windows is a generalization of the standard vehicle routing problem involving the added complexity that every garbage collection point should be collected within a given time window.

Genetic algorithms are best suited for solving vehicle routing problem with time windows. Other evolutionary algorithms like Ant Colony Optimization (ACO), Tabu Search (TS) are also used and the algorithm results are compared with the results of GA. The results obtained using GA are of good solution quality and save time (Olli Braysy 2001).

One of the innovative methodologies for the solid waste collection and transport is based on the Ant Colony Optimization (ACO) algorithm whose results show the most cost – effective alternative scenario and also estimate the running cost and simulate its application (Nikolaos et al 2007).

To measure the relative desirability of the remedial alternatives using the decision maker's value judgment as input for finding the site
suitability of dumpsite using Hierarchical Network Process (HNP), super matrix approach is published by Promentillae et al.(2006).

In the literature, it is reported that a competitive neural network model and a genetic algorithm are used to improve the initialization and construction phase of a parallel insertion heuristic for the vehicle routing problem with time windows. The neural network identifies seed customers that are distributed over the entire geographic area during the initialization phase, while the genetic algorithm finds good parameter setting in the route construction phase that follows (Potvin et al 1996).

The VRPTW is currently the focus of very intensive research, and is used to model much realistic application such as retail distribution, school bus routing, and mail delivery. The overall objective is to serve a set of customers at minimum cost with a fleet of vehicles of finite capacity operating out at a central depot (i.e. each route starts and ends at the depot). In this application, the objective is to minimize the number of routes and for the same number of routes, to minimize the total route time. To be feasible, the routes must also satisfy three different types of constraints. First, each customer has a certain demand, like a quantity of goods to be delivered. Since the capacity of each vehicle is finite, the total quantity of goods to be delivered on a route cannot exceed the capacity of the vehicle assigned to their route. Second, there is a time window or time internal associated with each customer. No vehicle is allowed to arrive too late at a customer location i.e. after the end of the time window. However, a vehicle can wait if it arrives too early, finally a time window is also included at the depot or garage. Each route must start and end within its time bounds. Time window acts similarly as capacity constraint, by expanding either the vehicle capacity or the time window at the depot; through this more customers can be serviced by the same vehicle (Potvin et al 1996).
The vehicle routing problem is of two types - Single Vehicle Routing Problem (SVRP) and Multiple Vehicle Routing Problem (MVRP). A SVRP is an umbrella description of three classical problems in operations research and transportation engineering, namely (i) the traveling salesman problem (TSP) (ii) the single vehicle pick-up and delivery problems (SVPDP) and (iii) the single vehicle pick-up and delivery problem with time window (SVPDPTW).

Partha Chakroborty and Arijit Mandal (2005) published an optimization algorithm for the general VRP. The algorithm uses mutation based GA called asexual GA. The algorithm is general. It can handle various types of VRP, namely TSP, SVPDP, and SVPDPTW. The proposed algorithm is fast and gives optimal/near optimal solutions with minimal computation effort.

The SVPDPTW can also be solved by using the family competitive genetic algorithm (FCGA). Genetic algorithms have been successfully applied to solve the combined computation problems. The family computation will improve the achievements for obtaining optimal solutions and the probability to hit the feasible solutions. When compared to traditional GA, FCGA approach does not need enormous resources. Application of FCGA to SVPDPTW, is successful in finding feasible solutions to all problems and obtained efficient results in experimentation (Wan-Rong Jih et al 2002).

Cellular Genetic Algorithm (CGA) is a subclass of GA in which the population diversity and exploration are enhanced. Such a kind of structured algorithms is especially well suited for complex problems. A study on behaviors of these algorithms produces better results in terms of the quality of the solution found, execution time and number of function evaluation (Enrique Alba and Bernabe Dorronsoro 2005).
2.4 GEOGRAPHICAL INFORMATION SYSTEM

To manage large amount of spatial data, GIS is an efficient tool to locate places, distance, accessibility, and proximity. It is a concept of standardized coding system i.e. unique identity for each elements like bins, collection points etc. The benefits of GIS includes timely response to the public, better decision making, comprehensive information presentation, timely data update, reduced data redundancy, improved data accuracy, improved data consistency, improved data compatibility, improved data accessibility, and enhanced data sharing.

GIS is an efficient tool for many application areas like site selection and finding optimal route, in solid waste management, urban transportation, water supply, and irrigation engineering.

In the solid waste management, the GIS is used for locating collection bins, selecting alternative place for dumpsite, and also for optimal routing of the collection and transportation vehicles. For selecting suitable sites for bin location or dumpsite, overlay analysis is used.

Syed Mahamood Anwar (2005), in his personal website published the use of GIS for selecting suitable locations for waste bins. The author’s website focuses on the waste bin location using Arc view PC network analyst with distances of 100m, 150m and 200m bin location from waste generation.

The general objective of the research is to find out whether GIS is the solution of SWM or not. The specific objectives are to:

a) Identify the present SWM practice by households and house-to-house waste collector in the study area.
b) Analyze the actor’s behaviour and the relationship among them in the SWM process.

c) Develop a GIS based model to propose the suitable location of community waste bins.

d) Assess the role of GIS for SWM in the existing context.

Based on that, a model is developed for SWM using GIS for location of bins in the Dhaka City Corporation. Waste bin should be located and distributed in such a way that people can identify them at a convenient distance. The assumptions made in the model are that

i) Physical settings like household distribution, density, road width, socio-economic, and existing solid waste management of Kalabagan have been taken into consideration.

ii) All the inhabitants of Kalabagan area are assumed to use the waste bins, which are situated within the Kalabagan area to dispose the waste.

iii) Real time consideration and population size of present time has been chosen.

iv) Inhabitants are free to choose a service between house-to-house or self-waste disposal to waste bin.

v) The waste generation points are considered to represent equal waste generation capacity which is 33kg.

On the same lines, Senthil Shanmugan (2005) published the experiences of developing GIS-MIS-GPS for SWM for a typical urban environment in the case of Bangalore city. 80% of the information used by the health official has spatial component. GIS is employed to integrate the voluminous data. The methodology used for developing the model is as listed below:
• Study and analyze the existing condition-maps, attribute data, reports, and the monitoring mechanism.

• Creation of the baseline data and the waste quantity details.

• Digitizing/demarcation of the existing health-ward boundaries.

• Software up-gradations to incorporate the details, to enter data (data entry – editing module), data viewing module (querying and the analyzing), MIS report & network compatible.

• Data entry of the details-spatial and attribute-bins, routes, quantity of waste.

• Generation of health-ward maps with all the existing details.

• Finalization of software and integration of the three modules GIS, MIS and GPS.

• Networking and Installation of the systems and monitoring.

• Training the official to handle the system and to update the data.

The logistics of the MSWM can be monitored through GIS models by keeping the objective as to increase the revenue base of the local bodies and deliver the services in an efficient way by taking appropriate planning and management arrangements (Aurobindo Ogra 2003). In the estimation and allocation of solid waste to bin through GIS, the triangulated irregular network (TIN) concept can be used. Based on this, the command area for waste allocation to a particular bin is generally located so the route slopes towards the collection points for ease of transportation by cart pullers. Computational results of bin location, type, size, and the frequency of removal are presented for typical urban area with known population density, income group distribution, road network and topology.
Precise estimation of solid waste generation and optimum allocation in commercially available bins with readily available discrete sizes can lead to a more rational and efficient design of collection, transport, and disposal systems. The GIS based analysis was carried out using TIN for waste estimation, allocation to bins, and removal frequency taking into consideration the available bin size, type, and placement possibilities. These are the basic parameters of a waste collection system and dictate the requirements for the waste transportation system from bins to disposal site. The criteria for attaching TIN to a particular bin based on shortest distance and descending slope is developed to ensure ease in transportation of waste by cart and tricycle pullers. This GIS-based computation for waste estimation and its optimal allocation to a particular bin can ensure functional and economical design of a solid waste management system (Ritesh Vijay et al 2005).

Dynamic modeling is also possible in the GIS environment. The model is devised to quantify the relationship between the demand and supply of suitable land for waste disposal over time using GIS and modeling techniques. Based on the projections of population growth, urban sprawl and waste generation, the method can allow policy and decision-makers to measure the dimension of the problem of shortage of land in the future. The procedure can provide information to guide the design and schedule of program to reduce and recover waste, and can potentially lead to a better use of land resources (Simone Leao et al 2001).

GIS is used to develop the Recycling Education Awareness and Participation (REAP), index for New York City’s neighborhoods (Clarke et al 2005).

GIS is quickly becoming a common tool in public health and there are many examples of GIS being used to map disease. Jennifer Evack et al (2006) presented how to improve the public health inspectors’ (PHI)
efficiency using GIS optimal routing technology. The goal of the project is to assess the value of optimum routing technology, to increase the number of inspection performed by PHIs, decrease the time spent on driving by PHIs, and develop a process for using optimal routing technology. Under the municipal GIS, Marcin Kunka (2006) presented the Abu Dhabi experience, stating that, geographical information systems are very essential part of day-to-day operations in many municipalities. It is important to utilize and maintain the data efficiently. Success of municipal GIS depends not only on allocated funds to finance, but also on the decisions with solutions to support. Spatial data should be better manageable and in the same time more accessible for larger groups of users.

The web-based applications should support workflow of the organization and streamline all services offered to the citizens. Vivek Shandas (2003) presented a GIS based water demand analysis for municipal application in Maps of India conference. Water demand indicates both current and expected water consumption in any given area over a specific time period. Due to varying requirements and spatially explicit characteristics of individual users, water demand must be determined separately for individual user groups. Multiple users of water can be differentiated according to the demand for potable water, industrial/commercial processes, as well as irrigation. The advantages of using a GIS for this analysis are that it helps initial identification of the parcels, visual cross checking with statistical data, and provides a platform for presenting the analysis to city officials for review. We hope that the study presented here establishes a basis upon which future research can examine fiscal and ecological implications of strategic water conservation strategies. The author Vaishali Nandan (2003) presented the Gorakhpur experience in municipal GIS. Municipal GIS is by far one of the most critical uses for the GIS. Almost all cities will have to conduct a similar exercise in the next several years due to the severe municipal financial crisis, even though it is generally mandated every five years. The magnitude of financial benefit from this is enormous.
After successful completion of the Gorakhpur GIS, pilot phase, the results were presented in front of the then Chief Secretary of the State, who gave the word for Municipal GIS to be initiated in all the towns in the State (Ghaziabad, Meerut, Agra, Kanpur, Lucknow, Gorakhpur, Moradabad, Bareilly, Varanasi, Allahabad and Aligarh). Bidding took place and work started in few cities.

Basnet et al (2002) published GIS based manure application plan. A GIS based framework for the development of manure application plan has been developed and a specific plan is presented for the Westbrook sub-catchment of Murray-Darling Basin, South-East Queensland, Australia. Data availability, concurrency, and accuracy are critical in developing a sound plan. Further refinement of the plan should focus on obtaining more recent, reliable and relevant data, improving the accuracy of the crop and manure distribution mapping, and refining the information available on both crop nutrient requirements and manure nutrient contents. The development of this plan has added a new dimension to manure management by:

- Providing a manure application guide for the whole sub-catchment while prescribing site-specific manure application rates to individual farms.
- Prescribing manure application based on a combination of social, economic, environmental, and agricultural factors.
- Using crop P$_2$O$_5$ requirements as the basis for the manure applications rate calculation and incorporating ‘environmental’ suitability in the final recommendations for the rates.
- Recommending practices to reduce the risk associated with manure application in areas of lower suitability.
- Providing necessary information for site-specific application of nitrogenous fertilizers based on the amount of ammonium nitrogen added to the soil by manure applications.
Jha (2001) developed a model for highway development using GIS, GA, and visualization. A model for highway development is presented, which can improve decision-making capabilities in selecting the preferred highway alternative. It can also enhance public and political acceptability due to effective visualization of future transportation enhancements. GIS serves as the prime source for necessary data and maps, and GAs are used to optimize highway alignments.

Various visualization operations, described in the study, are performed to effectively demonstrate future conditions. Highway agencies have often found that a minimum-cost highway alternative is not accepted by the public and politicians’ support is critical for the success of the project. This is due to the intangible factors whose effects are not considered in cost minimization. Effects of these parameters can only be obvious through detailed design and visualization. The feedback received from detailed design and visualization of future enhancements can be used as constraints in optimizations if necessary. This can also foster wider participation of decision-makers at early stages and help anticipate or avoid problems. Implementation of the proposed visualization approach in the example study provided significant time and cost savings and enhanced the project approval process. For finding the optimal bus service routes, GIS is best utilized and many authors (Karimi, 2004) developed an internet-based methodology to serve transit patrons on GIS environment. In this paper, an internet-based GIS-T (GIS-Transit) for optimizing bus riders’ activities is discussed. The design options and development strategies of the methodology are described in detail in order to provide transportation developers with insights into components, assumptions, and issues of internet-based GIS-T. On the one hand, the methodology provides bus riders with trip activities, while on the other hand, it helps transit authorities to schedule bus routes dynamically and offer bus services in an effective manner to the riders. Although a minimum number of bus-to-bus transfers are discussed as one criterion in the methodology, it is possible to customize the routing module to meet other
desired criteria such as travel time. In general, the design of the methodology allows customization to meet requirements of other transit bus services and other applications such as school bus routing.

The methodology presented in this paper provides bus services using different criteria. An example of which was presented for a minimum number of bus-to-bus transfers is desired. A prototype version of the methodology, called iBus, has been developed. The prototype does not utilize bus schedules in computations. A bus rider may have to wait for a long period of time at a transfer point, while other alternative route sequences may yield shorter travel time (even with greater number of transfers). By incorporating bus schedules into the routing module of the methodology, more practical route sequences can be computed.

In addition, the topology of bus routes strictly considers transferable bus routes to be the ones that share the same bus stops. However, a rider often makes a bus transfer in a nearby bus stop that is not located in the same street. This type of transfer is not considered in the current prototype because the two bus routes are not adjacent (connected) in the graph. Since this type of transfer can significantly reduce travel time, a buffer near the transfer points should be utilized when computing the optimal route.

Furthermore, Dijkstra’s algorithm may result in a low performance when the size of the bus routes becomes very large. In this case, alternative approaches, such as heuristic techniques, may be considered. Mapping performance could also be improved by using a simpler client-side user interface which is based on HTML and the Java Server Page, especially when the client machine is not up-to-date or the bandwidth is limited.

Mukti Advani et al (2005) presented a case study of Bhavnagar State Transport Depot for improvement in transit service using GIS. The optimization problem is formulated as one origin to many destinations kind of problem, with an objective of minimizing travel distance and travel time of
users. The constraints taken into consideration are impedances for intersection, type of road and speed. GIS emerged as a better tool for obtaining solutions of such complex problems very accurately and rapidly.

Muttiah et al (2003) developed an algorithm using simulated annealing to search a GIS database to locate suitable geographical sites for disposal of hazardous solid wastes. The results of simulated annealing were compared with an exhaustive method that sequentially searches the GIS map layers one raster cell at a time. The authors developed Indiana scoring model for setting hazardous waste disposal site.

Ramachandra and Saira Varghese (2003) took up Bangalore for their case study on municipal solid waste management. The authors dealt with the present situation of Bangalore city, and application of GIS - GPS system for solid waste management using MapInfo 5.5 as optimization tool. GIS system for waste management in IISc campus was developed. Planning of integrated waste management system for Bangalore was also given.

Thirumalaivisan and Guruswamy (2000), who arrived the optimal route for ambulance and fire service, used ROUTE module in Arc-Info. Chennai city is taken up for the case study. The route having minimum travel time is preferred over the route having the shortest distance. GIS can be used to address the objectives of finding the optimal route between the given origin and destination. It can be used to find out the routes involving shortest distances as well as shortest travel time. However, in order to achieve realistic results, the volume of traffic data has to be real time. Real time transmission of volume of traffic via satellite or through internet or using local micro wave transmitters is possible to receive online volume of traffic. This information may be made available in a suitable data exchange format so that it could be automatically added as attribute information in the road network.

Yogentharan and Jayakumar (2000) developed GIS database for Chennai city roads and discussed about the strategies for improvement. Data
base is developed for the entire road network using simple macro language (SML) in graphical user interface (GUI). The model is generated by Analytical Hierarchical Process (AHP) technique. Papacostas (2000) paper on “GIS application to the monitoring of bus operations” dealt with developing GIS prototype to monitor the schedule adherence for general transportation engineering and planning applications using node check survey and point check survey. Sutapa Samontha (2005), in his research paper titled “Travel time calculation with GIS in rail station location optimization” discussed in detail about the formulation of problem and the calculation of travel time using network analyst module. Network Analyst is found to be very efficient to calculate the travel times for the shortest routes between two points. The performance of the Algorithm depends on various factors, such as, the accuracy in modeling the route network, in calculation of the travel time cost, etc. The intensive the route network, better the solution. Integration of GIS makes the algorithm to compute the real travel time data.

2.5 GENETIC ALGORITHM

One of the meta-heuristic algorithms used in the optimization problems is Genetic Algorithm. A large number of researchers utilized the genetic algorithm as an optimization tool, particularly in transit network design. The objective of using GA in transportation network is based on an analytical model, supplying a synthetic analysis of network performance of optimization procedures. This is for solving the network design problem by determining transit routes, associated frequencies and locating main transit centers.

Genetic algorithms are search algorithms based on concepts of natural selection and natural genetics and are used as general purpose optimization algorithms. They differ from other search methods because they search among a population of points simultaneously and work with a coding parameters rather than the parameter values themselves.
The heuristic transit network design method proposed by Gaetano Fusco et al (2005) assume to give the Origin/Destination(O/D) matrix demand, the road network characteristics, and the vehicle capacity as well as operating costs and users costs. The basic framework of the model is established on the following three phases:

Phase 1 : a heuristic algorithm to generate a set of feasible routes.

Phase 2 : a genetic algorithm to find the optimal sub-set of routes with associated frequencies.

Phase 3 : final improvement of the network configuration.

The author, Chulming Jun(2004) discussed the problem of finding the minimum cost path in the network of multi-modes of public transportation. For finding the optimal path in the transportation network, the minimum total time path is considered rather than minimum distance.

Partha Chakroberty et al (2001), describe how to simulate the transit network in GA. This paper uses the simple binary coded genetic algorithm based approach for optimal fleet size distribution and scheduling with transfer consideration for a transit system. The total wait time of the passenger is taken as the sum of the total initial wait time of passenger and the total transfer time. The problem is formulated as a non-linear mixed integer programming problem is shown in equation (2.2).

Minimize

$$
\sum_{i} \sum_{j} \sum_{k} \sum_{l=1}^{n_i} \sum_{i=1}^{n_j} \delta_{i,j}(d^k_j - a^k_i) \omega_{i,j}^k
$$

$$
+ \sum_{i} \sum_{k} \int_{0}^{x_i} v_{i,k} (t)(d^k_i - d^{k-1}_j - t)dt
$$

(2.2)
Subject to:

\begin{align*}
G1: d_i^k - a_i^k & \leq s_i^{\text{max}} \quad \forall i \text{ and } k = 1, 2, \ldots, n, \\
G2: d_i^k - a_i^k & \geq s_i^{\text{min}} \quad \forall i \text{ and } k = 1, 2, \ldots, n, \\
G3: a_i^k - a_i^k & \leq h_i \quad \forall i \text{ and } k = 1, 2, \ldots, n, \\
G4: (d_j^l - a_i^k) \delta_{i,j}^{k,l} & \leq T \quad \forall i, \forall j \neq i \text{ and } k = 1, 2, \ldots, n, \text{ and } l = 1, 2, \ldots, n, \\
G5: d_i^j - a_i^k + M(1 - \delta_{i,j}^{k,l}) & \geq 0 \quad \forall i, \forall j \neq i \text{ and } k = 1, 2, \ldots, n, \text{ and } l = 1, 2, \ldots, n, \\
G6: & \sum_{i=1}^{n_i} \delta_{i,j}^{k,l} = 1 \quad \forall i, \forall j \neq i \text{ and } k = 1, 2, \ldots, n, \\
G7: & n_i \geq n_i^{\text{min}} \quad \forall i, \\
G8: & \sum_{i=1}^{n_i} n_i = N
\end{align*}

(2.3)

The use of GA is particularly suited for the scheduling problem, which reduces the difficulties arising due to large number of variables and constraints, the discrete nature of variables, and the nonlinearities involved in the objective function and the constraints. In optimization problems on road network, either the Dijkstra’s algorithm or Floyd’s minimum path algorithm (Partha Chakroborty et al 2002) were used. The different route set for the study area will be considered as the initial route set, from which the optimal route will be arrived (Pattnaik et al 1998).

The genetic algorithm which is a high-level simulation of a biologically motivated adaptive system is the tool for selecting the optimal route network. There are two methods based on the coding scheme which can be used for solving the problem by genetic algorithm, namely, fixed string length coding and variable string length coding.

In the fixed string length coding, routes are considered as variables and the number of routes considered during genetic operation remains fixed. This demands iteration for the number of routes to arrive at optimum configuration. But in the variable string length coding, the number of routes
and the set of routes are selected simultaneously, thus avoiding any iteration for the number of routes.

Network design with conventional approach poses considerable difficulties owing to the combinatorial nature of the problem. So GA was used to overcome the difficulties.

The artificial intelligence technique of genetic algorithms (GAs) is used to minimize the overall travel cost in the network design. There are a number of transportation applications that require the use of a heuristic shortest path algorithm rather than one of the standard, optimal algorithms. This is primarily due to the requirements of some transportation applications where shortest paths need to be quickly identified either because an immediate response is required or because the shortest paths need to be recalculated repeatedly. For this reason, a number of heuristic approaches have been advocated for decreasing the computation time of the shortest path algorithm (Fu et al 2006).

Huang Bo et al (2004), explore a novel approach to evaluate the risk of Hazardous Materials (HAZMAT) transportation by integrating GIS and GA. A set of evaluation criteria that are used to route HAZMAT vehicles is identified and assessed. The criteria considered are related to safety, costs and more importantly, security. A GIS is employed to quantify the factors on each link in the network that contribute to the evaluation criteria for a possible route, while a GA is applied to efficiently determine the weights of the different factors in the hierarchical form, allowing for the computation of the relative total costs of the alternate routes. Therefore, each route can be quantified by a generalized cost function from which the suitability of the routes for HAZMAT transportation can be compared. The proposed route on a typical position of the road network in Singapore is presented.

The advantages of finding optimal routes are reductions in fuel consumption and labour cost arise from the optimal design of SW collection
routes. Further, optimal design can reduce vehicle maintenance expenditures and improve traffic conditions in urban areas. The optimal routes have been developed according to intuitive methodologies and field experience. However, increasing attention is being devoted to innovative approaches, such as those able to simulate complex collection systems. To analyze the complexities, operational research applications are used. They are typically based on the implementation of heuristic procedures allowing for high quality solutions to the problem at hand.

A genetic algorithm, a search algorithm motivated by the principles of natural genetics, is selected to solve the transit route network design problem because of its simplicity, robustness, and ability to handle large, multi objective and complex problems. GAs provide efficient representation of the problem, and the coding aspect inherently takes care of the constraints / boundary conditions, and feasibility of decision variables (Partha Chakroborty et al 1995).

The major drawback of the GA-based model is the expensive fitness evaluation in each generation, for each individual of the population, and for the large route network design problem, which is combinatorial in nature. However, each of the fitness evaluations for a given individual in a population of a generation is independent of other individuals. This feature of GA models can be exploited in a parallel computing environment to reduce the computational time (Jitendra Agarval et al 2004).

The step-by-step procedure of chromosome representation, population initialization, selection, crossover, and mutation process in GA was explained by Xingdong Zhang (2006) for locating multi objective corridor problem.

The optimal allocation of buses with a conventional approach poses considerable difficulties owing to the combinatorial nature of the problem and the complex nature of the route choice model. Hence, genetic algorithms
(GA) are proposed as the computational tool because of their ability to handle large and complex problems. Kidwai’s (2005) paper on “A Genetic Algorithm based bus scheduling model for transit network” is solved in two levels. In the first level, minimum frequency of buses required on each route, with the guarantee of load feasibility, is determined by considering each route individually. In the second level, the fleet size of first level is taken as upper band and fleet size is again minimized by considering all routes together and using GA.

James Cunha Werner (2002), proposed a data modeling structure which permits an easy simulation of distributed systems’ association with GA. This is to solve the problem of scheduling and rescheduling and is applied to settled route (train/ tube/bus transport system).

Srinivasalu (2006) took up Cuddaph for case study. It was on the evaluation of Normal, Emergency, and Optimal paths for a solid waste management network of an Indian city. The paper focuses on identifying the optimal paths from transport points to disposal sites using shortest route algorithm, transportation problem, and minimal spanning tree. The transportation problem explained by the authors had the objective of minimizing the transportation cost from each transfer point to disposal site and is given by the equation

\[\text{Minimize, } Z = \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij} x_{ij}\]

Subject to
\[\sum_{i=1}^{m} x_{ij} \leq s_i \text{ for every source } i = 1 \text{ to } M\]
\[\sum_{j=1}^{N} x_{ij} \leq s_j \text{ for every destination } j = 1 \text{ to } N\]

where, \( C_{ij} = \text{Cost of supply a unit product from source } i \text{ to source } j \)
\( X_{ij} = \) Number of units of product supplied or transported from source i to destination j

\( S_i = \) Supply capacity
\( S_j = \) Destination capacity

### 2.6 LIMITATIONS OF CONVENTIONAL METHODS

Some of the researchers used GIS tools for optimization, some of the researchers used evolutionary algorithms like GA, ACO, Artificial Neural Network (ANN), SA and Fuzzylogic for optimization and very few integrated the evolutionary algorithms with GIS as a hybrid approach. Most of the authors utilized the ArcView GIS with an overlay analysis. In the hybrid approach the priority was set using any one of the evolutionary algorithms. For simulation of the collection route, most of the authors treated the problem as simple traveling salesman problem of transportation problem. Very few utilized the concept of vehicle routing problem which is a division of transportation problem. In the vehicle routing problem, there are two categories namely simple pick-up and delivery point problem and pick-up and delivery with time window problem.

The waste management system applied in most cities in the world are dominated by landfills, rather than going for recycling, composting, and combustion facilities. This is due to the low economic cost of landfills and their ease of implementation. However, of all waste facilities, landfills have the largest demand for land. This demand has been increasing with the increase in waste production. On the other hand, land is a resource whose availability has been decreasing in urban systems. Indeed, space or urban land is a limited resource and also is a good market with increasing value. Thus, there is a serious problem of the contradictory behavior of the supply and demand for land in cities.
The research work utilized the present requirement of using the landfill site effectively and incorporating time window in the collection and transportation vehicle routing problem of MSW.

2.7 REVIEW OF NEWSPAPER ARTICLES

The newspaper articles collected from 2002, show the importance given to municipal solid waste management. On December 4, 2002, in ‘The Hindu’, an article with the title “No need for a bill to ban plastics” came up. Plastic is used in a variety of application. The article stated, “It would be best to drop the bill altogether and take efforts to implement strictly the centre’s notification on plastic bags and the BIS standard on plastic bags”. On December 19, 2002 in ‘The Hindu’, in corporation’s ban order / penalties collected column, “intensive drive against plastics” was published. The Madurai Corporation has started implementing ban on non-degradable plastics effectively. A concerted drive, undertaken by officials, yielded a revenue of Rs. 24,000 as penalty levied against those who manufactured, stored, and sold plastics of less then 20 microns on single day (Tuesday). A raid in west zone alone realized Rs. 10,500. “The corporation seized 1,400kg of banned plastic materials from them”, the Commissioner, A.Karthik, said. The ban on plastics is insisted mainly to reduce the quantity of waste plastic in the MSW which is not picked up by rag pickers. Waste plastic creates eyesore, and unaesthetic appearance leads to soil pollution.

On December 24, 2004, in “The Hindu”, in Madurai District/Public involvement sought column, “consensus on disposal of plastic waste” was published. According to it administration, civil body, manufactures, and users of plastic chalked out a plan for disposal of plastic waste in Madurai district. Under the arrangement, individual houses and business establishments would be required to segregate garbage at source and the vehicles of civil bodies would pick them up for disposal. The plastic manufactures’ association of Madurai has agreed to grade the plastic waste
and segregate it for a possible use for road laying. At a meeting convened by the Tamil Nadu Chamber of Commerce and Industry, the then collector, Mr. S. Ramachandran, emphasized the fears of manufactures over a blanket ban on plastic use. He stressed that the problem was with the disposal of plastic and not its use and outlined the objective of making Madurai free from plastic waste. In “Dinamalar” dated 09.06.2004, an article “revenue gained from garbage for corporations and municipalities”, outlined by the collector Mr. Rajendran. He stressed about the segregation at source of biodegradable and non biodegradable waste which can be best used for road laying. Every year there are few articles in newspapers. From 2008 onwards, almost every newspaper has atleast one article on environmental (degradation) pollution. In “Dinamalar” dated 12.02.08, in the complaints box column, an article states that there are lack of waste bins at Ellis Nagar, Pookkarathoppu Street. So, the street looks ugly due to the scattered garbage. On 12.02.08 in “The Hindu” in an article entitled “Living around mounds of waste – Improper disposal of waste proves to be a health hazard for many residents”, The authorities of Thiagarajar College of Engineering have taken up the issue with the corporation. “It is a major health hazard. This area is also highly infested with mosquitoes and, if unattended, it will become the starting point for diseases”, says Karamuthu T. Kannan, correspondent of TCE. A study conducted by TCE has revealed that pollutants concentration level is above permissible level and the groundwater too has lost its potable value.

An article in “Dinalamar” on 05.02.09, talks about the renewal of ‘no objection certificate’ issued on expansion of Airport during 2004 by Central Ministry of Aviation and International Standards. A part of 380 acre dump-yard posed problem for landing of airports and few accidents were reported due to the birds in the dump-yard crash with airport. Now, the corporation has taken steps to convert the dump-yard as sanitary landfill site. The project will be taken up at a cost of Rs.56crores, under the Jawaharlal Nehru National Urban Renewal Mission. The newspaper articles revealed
some glimpses about the diseases, lack of waste bin and different types of pollution due to the municipal garbage.

On 27.06.09, an article in “The Hindu” reveals that the possibility of setting up solid waste management clusters for efficient management on the line of the Vankatamangalam model is being explored, according to Deputy Chief Minister M.K. Stalin. Initiating a debate on the demands for grants to municipal Administration, water supply, Rural Development, and Panchayatraj Departments, Mr. Stalin said agreements had been concluded with different private agencies for leasing out land to implement the solid waste management scheme on the basis of build, operate, and transfer in Coimbatore and Madurai Municipal Corporation and Namakkal municipality.

On 02.07.09, almost all news papers published the news about converting the MC dump-yard into sanitary landfill site. According to the press release, Mayor along with P.M. Mannan, Deputy Mayor, S. Sabastine, Corporation Commissioner, K. Shakthivel, Superintending Engineer, S. Mathuram, Executive Engineer and other officials inspected the garbage dump-yard. The garbage dumping ground was being maintained at an expense of Rs. 56 crore. Here the garbage, segregated as degradable and non-degradable and the degradable wastes will be send for compositing and the non-degradable waste will be disposed off scientifically. Every action would be taken to protect the ground water. Eight lakh cubic metres of garbage dumped on the 110-acre yard has been accumulated on 21 acres of land using compaction technique. “This will ensure that there will be no more smoke emission due to burning of waste” Mr. Sebastine said. Necessary permission from the Director General of Civil Aviation has been received for it. Chief Engineer. K. Sakthivel said that green cover would be put over the closed garbage. Every year officials of Tamil Nadu Pollution Control Board would inspect it. “The closed garbage will become harmless after 20 years and thereafter it will not require any maintenance”, he said. Besides, this activity would reduce bird menace for aircraft landing and taking off from Madurai
airport. Preparation of two landfills on 46 acres was under way. The corporation generates 450 tonnes of garbage daily and out of this, around 100 tonnes is inorganic waste. This will be used for the landfill which will not pollute ground water. The proposed project will take care of land filling for the next 30 years. The organic waste will be converted into manure.

2.8 SUMMARY

A quite large number of researchers utilized the GIS tool for transportation and municipal services. Case study analysis needs to be carried out for studying the performance and suitability of the optimization technique. Some of the researchers utilized the concepts of evolutionary algorithms for municipal services and transportation.

Some researchers considered the simple vehicle routing problem for the urban bus transit. In VRP, the time window concept will be applicable for more efficient handling of vehicles and labors. Especially in solid waste management, is most important for removing the garbage from the entire city.

A few researchers used the time window concept in the transit system. Much less work has been reported in the two types of vehicle routing problem, namely the simple pick-up and delivery problem, and the pickup and delivery with time window problem. A great emphasis needs to be given to the urban solid waste transportation system, as the future demand for transport can be met only by the corporation, especially in developing counties like India.

This literature review confirms the view that vehicle routing problem with time window is the most efficient means in municipal solid waste collection and transportation route optimization.