A CLASSICAL HEURISTIC ALGORITHM IMPLEMENTATION FOR LOGISTIC ANALYSIS OF WASTE COLLECTION PROBLEM: A CASE OF ADDIS ABABA ARADA SUBICTY

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ABSTRACT

This paper intended to implement classical algorithms for logistic problem especially in revers logistic by using waste collection process to demonstrate. Along with its strategic nature and possibility for realization using analytical method, waste collection process considered as a vehicle routing problem, which is beyond solid waste management, instead a city logistic problem where optimization is demanding. For the case problem, mixed integer programming mathematical model deployed to node routing problem-capacitated vehicle routing with the objective of minimizing total collection cost. Local search based on 2-Opt and Or-Opt improvement heuristics used to solving model based on initial solution obtained from Clark and Wright (saving method). Model relaxed to both Hamilton cycle and Hamilton path to accompany case problem and verified by problem instant with optimal solution cited. Due to relative operational data availability, Arada-subcity considered and coordinate of waste bin obtained using geodetic information on the Google earth while problem parameters determined based on the secondary data. . Model validation done using distance traveled and utilization of vehicles in the route and substantial result obtained with a saving of about 29.453 % in kilometers traveled per year and an increase of vehicle utilization from 68.19 % to 95.46% for each route. The finding shows a need of revision on the current practices of waste collection process in one hand and how classical heuristic are both potential and essential for solving problem of interest in the other hand.

Keywords: Classical heuristic, Logistic Analysis, Optimization, Vehicle routing

INTRODUCTION

In a solid waste management, the collection process estimated to consume 70 up to 80 % of operational cost [1] in developing country and 60-80% at global level [2-4].Whereas according to the report by World Bank and USAID, of the annual allocated budget of the municipal, 20-50% spend to solid waste management [5]. Consequently, since collection rout design is viable [4] in mitigating the problem ,integrating and combining those factors like storage facilities route, transporting mechanism and vehicle distribution and disposal strategy is becoming interest of research[1,2,4], [6,7,8,9,10] and in fact is a kind of an optimization problem. Optimization of waste collection routing as city logistic[11], is therefore, a decision upon for example, which streets must each vehicle follow, which containers should each one of them collect and how many trucks should a fleet for a given city have.

The minimum cost at the underlying of customer satisfaction should be addressed and cost reduction in waste collection routing consist (i) minimizing vehicle trip to disposal site, (ii) optimizing the collection routing and (iii) maximizing the number of full loaded trip to the disposal site.

In its search space, optimization process is either continuous or combinatorial and combinatorial optimization problem (COP), deals to find the optimal solution (i.e. arrangement, grouping, ordering or selection) from a finite set of objectives to optimize (maximize or minimize) a function of discrete variable. Of course, the task of researchers in the area is to make ready the optimization problem for converting to decision problem, which always is either p or NP class [12]. The waste collection routing problem that can be simply taking as vehicle routing problem is an NP-hard, as it is difficult to have Polynomial algorithms to find the solution [13].

Vehicle routing problems (VRP) is a generic route management problems that could possibly extended in to various VRP variants. The mathematical formulation proposed by Baldacci, et al., [14] for generic VRP is based on the various assumptions regarding with capacity utilization, depot type, vehicle homogeneity, rout vehicle combination etc. Regarding to the actual logistic operation especially in urban areas the problem is a type of combinatorial optimization problem and can be formulate using two different mathematical problems, node routing problem [15] (the classic VRP/CVRP) and Arc routing Problems (ARP)[16].

Practically, the solid waste collection system in case of Addis Ababa city seems well fit for both modeling. For the latter case, those organized collectors are expected to collect the various inhabitants' waste along the road near whilst the waste collection process by the agency using the transfer stations “the containers” is a kind of node routing and is the concern of this study. The waste collection process of the case study has been characterized with that of (i) containers have been emptied more than a week (ii) vehicles sometimes found Visiting collection points without service, “deadheading operations” and (ii) in balance route , overflow of wastes resulted from vehicle overload in some street and routes with under load capacity in other routes. The annual vehicle load utilization however found to be about 68%.

The study aims to optimize vehicle routing for the waste collection process by formulating a mathematical model and selecting the solution approaches for optimal vehicle routing. The remaining of the paper includes in section two a review of optimization solution approaches and waste collection optimization while section three about methods and material presentation. Result and discussion presented in section four with an optimal solution of the case study. Finally, conclusion is made and future work drawn in section five.

LITERATURE REVIEW

Solid waste management is the action of collection transportation, storage recycling or disposal [4], [8] while solid waste management system consists of plans for how to manage the waste and plants for treatment [17]. The objectives behind solid waste management are vast but with at the heart of minimizing the adverse effect of the solid waste Tanaka, M (1998) in [15]. Concerning to the collection process the objective is either of travel time and /or travel cost, minimize number of vehicle route compactness, personnel and workload balancing [4], [8] Different solid waste management models like Cost Benefit Analysis (CBA), Life cycle Analysis (LCA) and Multi-Criteria Decision Analysis (MCDA) being forwarded [18]. The distinguishing factor for those models however, is either the goal or the methodology. It is the Cost benefit Analysis that hysterics with aim of this study problem From the logistic point of view, the municipality solid waste system has two basic planning tasks, location of facilities (plants, depots, warehouse, i.e. containers in this case etc.) and routing of vehicle and a kind of Strong NP-hard problem combining these two task is known to Location Routing problem (LRP).

To the best of our knowledge, the first article related to the optimization of waste collection routing is a paper studied in United States of America[19] for New York and Washington Dc cities. Following USA countries like Trabon, Turkey [10], Barcelona [20], Athens, Greek[21],Hanoi, Vietnam [22], and Porto Alegre, Brazil [23] tried to minimize the cost by optimizing collection routes. Related to the application of VRP variant to the solid waste collection process, it is VRPTW that has been employed in a great extent [11], [24], [25].

Waste collection process modeling problem and solution approach consequently become an important question in the optimization process and the vehicle routing problem for waste collection process is not far away for effect of the mathematical expression. To mention such mathematical model for instance linear programming [26] to optimize the solid waste disposal system, [27] to minimization cost of collection, transfer, refuse to energy (RTE) and disposal .However, due to the requirement of real world problems, a restriction has been invited on the domain of the decision variable and mixed integer programming (MIP) is to be mentioned especially when there is a need to make an entity either passive or active. The municipal solid waste generation model based on cost optimization by [28] at different level of the waste management stage, a non-linear model for decision support of planner to the optimal number of landfill [29] are MIP. The comparative analysis made by Hasit and Warner [30] between linear programing (LP) and MIP shows that the latter performs well especially for increased facilities and discrete size of resource. Solution approaches must always come next and in an optimization problem, it has been generalized to have exact method, approximate method and heuristics method [31].

In exact method, the advantage is in getting of best solution (exact solution) despite of the unreason able amount of time needed especially when size of problem increase. Branch and bound and dynamic programming are the most approaches in an exact method that researchers has employed [32-34]. For an increase problem size, the aim is not to have exact solution rather an optimal one and an approximation method has been proposed to be employed as approach based on the approximation ratio α for the feasible solution.

For the optimization problemsO_p, if the algorithm θ solves the problem instance$I_n \in O_p$ and θ can give a feasible solution forI_n, the definition for the approximation ratio α depend on the measure of the $\theta(I_n)$ and the measure of an optimal solution Opt(I_n) that is, $\alpha(\theta) = min\frac{m_{I_n}\theta(I_n)}{m_{I_n}\mathrm{Opt}(I_n)}$. Beside the degree of the final solution obtained, there is another very important difference between exact and approximate method, that is exact method can prove that no solution exist in the case problem.

Heuristic method is either rout building that start from scratch or route improving by which an algorithm that tries to produce an improved solution because of an already available solution.

Having of the computational complexity O($n^2 \log n$) as an advantage to be solved in a polynomial time the Clark and Wright method since it introduced several enhancements have been proposed for it. Gaskell (1967) and P. Yellow (1970) in [34] for instance proposed $S_{ij} = c_{i0} + c_{j0} - \lambda c_{ij}$ for route shape λ parameter weighing relative importance of c_{ij}. For the other parameter μ Paessens (1988) in [34] improved the saving algorithmto $s_{ij} = c_{i0} + c_{j0} - \lambda c_{ij} + \mu |c_{io} - c_{jo}|$.

Remarkable improvement even from the best known solution was obatined by Gilbert, et al. [35] when the parallel version of Clark and Wright method combined with a 3-Opt local search heuristcs. The result obtaine by the paralle saving method outperform the sequential one and it was on average of 6.71% above the best known solution when combined to 3-Opt.

The 3-Opt. method however is an improvement hueristic under the general terminology of the r-Opt(or sometimes called K-Opt) by which about r arcs are to be removed and replaced by the other r arcs and the neighborhood obtained and cannot be improved further is an r- Opt optimal. Both 2-Opt and 3-Opt improvements are a local search heuristics under r-Opt, r $\in (2,3, \ldots . n)$ and ncreasing the value of r guarantees a better solution with higher computational effort [36]. As a modification for r-Opt, several approaches has been researched like Lin and Kernighan (1973) and Or-Opt by Or (1976) in [35]. While it is the Or-Opt which aims in displacing strings of three, two or one consecutive vertices to another location utilized in this study These three options of the Or-Opt denoted in this study as Or-Opt [3], Or-Opt [2] and Or-Opt [1] respectively to the three, two and one vertices displacement. As cited in [37] about local search in a combinatorial optimization, E.Aarts and J.K Linstra (1996) found that the 3-Opt outperforms the 2-Opt only by 2% for 100 customer problem. While the 4-Optalgorithm is not better than 3-Opt algorithm, the longer the value of r the longer it would take the computational time. Or-Opt algorithm on the other hand has an advantage over the 3-Opt. In 3-Opt it is must to reverse the direction of route and there is a possibility of obtaining infeasible solution whereas the Or-opt operator can keep the route direction and guarantee a feasible solution.

Output quality of the local search heuristics however depends both on the initial solution and the mechanism of the neighborhood used and that is why the Clark and Wright method applied here to intiate the solution.

Generally, with respecte to modeling issue and from the logistic point of view, the municipality solid waste system has two basic planning tasks, location of facilities (plants, depots, warehouse, i.e. containers in this case etc.) and routing of vehicle. As a gap identified theoretically, local search or improvement heuristic potentially depends on both the initial solution and the mechanism of the neighborhood use*d, whereas* of the reviewed result what a researcher have emphasized for is the latter and no literatures found to deploy construction heuristics to initiate improvement heuristics as what we perform by using saving.

Methods and Materials

For the realization of the cas study waste collection process the problem has to be defined and a coceptual model supposed to be develpbed alnog with decicion variable and parameters of the problem.

Problem Description and Concetual Model Development

Tomodel mathematicalythe case study, a description of the prblem made based on the generic capacitated routing problem (CVRP) and a single depot with a homogeneous fleet of vehicle. For set of homogeneous vehicles K, set of collection point P, the CVRP mathematically can be described by a directed graph$G = (V, A)$, which consists (n+1) vertex for $V = n = 1$ the depot, $V = ,2,3 \ldots .. n$ are collection points and $V = n + 1$ the landfill. While$A$ represents the arcs for $A = \{(i, j): i, j \in V, i \neq j\}$to form a connection between depot and collection point and among collection points. The vehicles leave the depot empty, collect the waste of each customer at each collection point P to transport to the dump site and return to the depot empty. The objective of the study is to find the set of vehicle routes servicing all the customers with the minimum total distance.

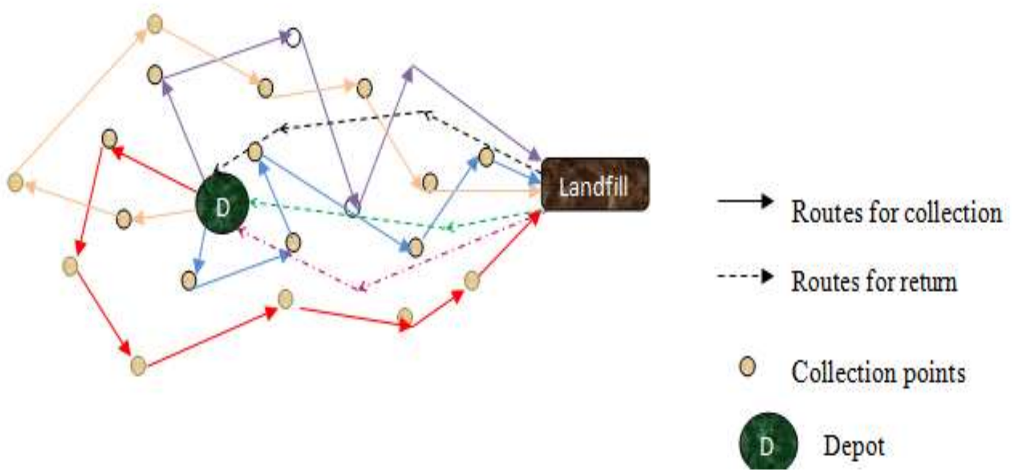

Figure 1 Schematic representation of collection route path

Variable, Parameters and Mathematical Model

x_{ij} : The binary variable "decision variable" and x_{ij} is one if the vehicle k traverse arc (i, j) otherwise zero.

Q: The maximum allowable capacity of the vehicle (in kg)

q_i : The amount of waste at a collection point i, for$i = 2 \ldots . n, q_i = 0\ for\ i = 0\ and\ i = n + 1$.

d_{ij} : Euclidean distance between points $i\ and\ j$.

Moreover, each collection point (v= 2...n) can designated as C ∈ $(c_1 \ldots \ldots \ldots .. c_n)$

An assumption then drawn for the implementation of integer programming as follow

i. The collection process of the waste for the model starts at the point where residential waste accumulated and ends at the landfill
ii. No consideration is given to the separation of the waste at all
iii. The collection point for the solid waste is for all waste generator agents (residential, institutions, industries)
iv. Transpiration cost is a function of the distance traveled
v. All tours start and end at the single depot
vi. The effect of the traffic congestion on the total cost for the objective function is trivial

vii. All collection centers are nearby to the street of the truck

The conceptual model assumes no plant for recycling, compositing or incinerating. Hence, the objective is to minimize the total distance traveled to reduce the transportation cost of the solid waste from various collection point to the disposal site. The mixed integer-programming model is formulated and each of the constraints like degree constraint, flow constraint, capacity constraint and sub tour constraints considered by respective equations.

$$Minimiz\ Z = \sum_{i\in V}\sum_{j\in V\setminus i}\sum_{k\in K} d_{ij} \quad (3.1)$$

$$\sum_{i\in V}\sum_{k\in K} x_{ij} = 1, \quad \forall j \in c \quad (3.2)$$

$$\sum_{j\in V}\sum_{k\in K} x_{ij} = 1\ , \quad \forall i \in c \quad (3.3)$$

$$\sum_{1}^{k} x_{1j} = K, \quad j = 2 \ldots n \quad (3.4)$$

$$\sum_{1}^{k} x_{j,n+1} = K, \quad j = 2 \ldots\ldots n \quad (3.5$$

$$x_{n+1,i} = k, \quad for\ i = 1 \quad (3.6)$$

$$\sum_{i\in V} x_{ij} = \sum_{j\in V} x_{ji} \quad \forall i,j \in V\setminus\{1, n+1\} \quad (3.7)$$

$$\sum_{i\in C} q_i \left[\sum_{j\in V} x_{ij}\right] \le Q\ \forall ij \in v, i \ge 2\ , i \ne j \quad (3.8)$$

$$u_i^k - x_j^k + Q x_{ij}^k \le Q - q_i \quad (3.9)$$

$$\mathrm{q_i \le u_i \le Q, \quad \forall i \in V\setminus\{0, n+1\}} \quad (3.10)$$

$$x_{ij} \in \{0,1\} \quad \forall i,j \in V, k \in K \quad (3.11)$$

$$Q, q_i\ and\ d_{ij} \ge 0\ ,\forall \quad (3.12)$$

A two-phase local search applied, the Clark and Wright method in the first phase, 2-Opt and Or-Opt heuristic implementation in the second phase. This is because of that the outcome of the local Search is dependent to both initial solution and mechanism of the neighborhood used and hence this study applied the Clark and Wright method to initialize the solution.

For the vehicle capacity Q and customer demand q_i at each point, Clark and Wright method implemented using the following procedures.

- Generating rout r_i, $for\ i = 1, 2..n$ to get for instance, $r_1 = 1 - i - 1$ and $r_2 = 1 - j - 1$ for customer $i\ and\ j$ and starting point of 1 (depot.) (figure 3)
- Calculate the savings S_{ij}using $S_{ij} = d_{1i} + d_{j1} - d_{ij}$
- sorting down the list of saving in decreasing order
- Assigning the customer to the route starting with the highest saving

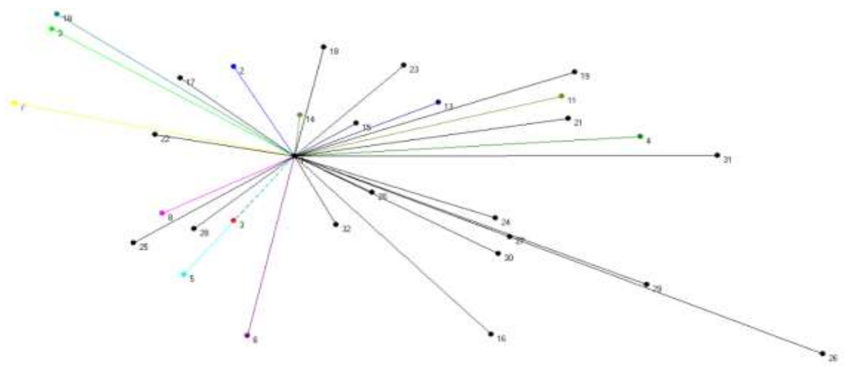

Figure 2 Generated route (for 31 customer points)

The generated route then has to be combined keeping that (a) the combined route cannot exceed vehicle capacity $(d_i + d_j \leq Q$, (b) no insertion is possible in the interior of the tour. While merging the rout combination operation applied iteratively to pertain the parallel version of the saving method. Constraint 3.5 gets relaxed both in the initial solution and improved one to a a Hamilton path with d_{jl}^{e} denotes the distance between the end customer point j and the landfill, d_{1l} is the distance between depot and landfill and hp_{di} is the Hamilton path of route i. Once the initial solution initiated using the saving method, the local search improvement heuristics deployed based on (i) intra- route (figure 6. a) and (ii)

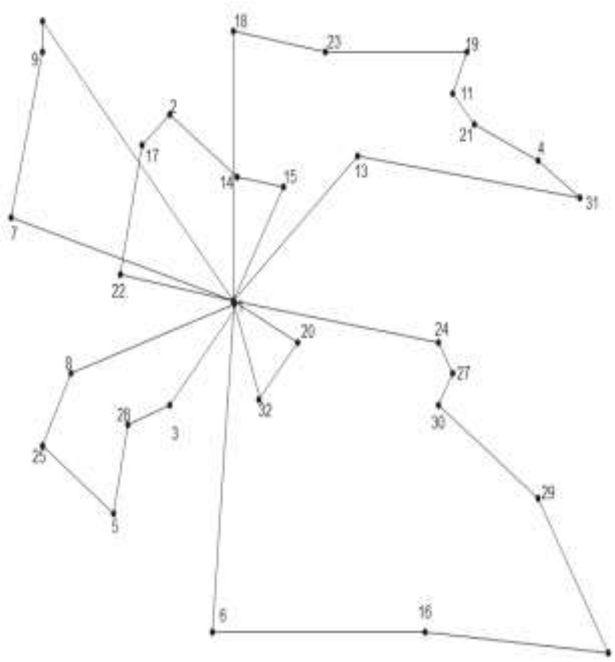

Figure 3 Hamilton cycle of the initial solution (obtained from VRP-solver)

inter-rout (figure 6. b) operations to improve the solution. while applying the immprovement heuristics ,instead of chossing the best pairing of route at each step, a pair of routes sellected at random so as not to be trapped locally and choose the best overall solution.

dummy distance d_{jl}^{e} between each customer of the rout and depot of the Hamilton cycle (figure 4). Equation 3.13 gives the total distance of the optimized solid waste collection route (Rd_{opt})

$$Rd_{opt} = \sum_{i=1}^{R} \sum_{j=1}^{R} \left(d_{jl}^{e} + hp_{di}\right) + m * d_{1l} \qquad (3.13)$$

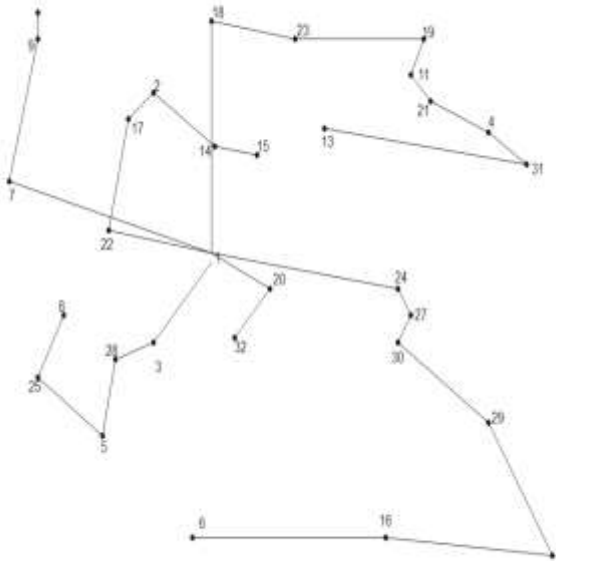

Figure 4 Hamilton path of the initial solution

The 2-Opt operation is an intra-rout operation and for a given feasible tour T the improvement algorithm repeatedly performs atour modification based on exachanging or moves until a tour is reached for which no operation yileds an improvement (locally optimal tour). To effect this k routes randomlly sellected from the resultd saving algorithm then two edges from the hamiltation path are removed (edges with doted line in figure 5) to have a paire of arcs $(i, i+1)$ and $(j + j + 1)$ and removing of these edge is to replace one edge by another .i.e. $\{i, i+1\}\{j, j+1\} \rightarrow \{i, j\}\{i+1, j+1\}$.
The 2-Opt algorithm adpoted is based on $O(N^2)$ so as to sellect two arcs (a_i) to be replaced in order to construct a new cycle (route).

K is the number of arcs being replaced and N is the total number of arcs available in the route while letter G is the graph of the cycle that consists of $a_1\, a_2 \ldots a_{N-1}$ arcs with a Hamilton cycle of total length TL (G). $G_{current}$ Indicates the incumbent graph of the problem which possibly replaced by the new graph G'.In the 2-Opt operator the neighborhood of graph G searched by removing arc(i, j) and $(i + 1, j + 1)$.

The process continues until no improvement is made and it is the total length, which helps in determining the exchange. As described Or-Opt is a modification of K-Opt and its advantage over 3-Opt is it can keep the route direction (figure5) and and guarantee a feasible solution. Of course Or-Opt can be considered as part exchange of 3-Opt (i.e. a section of route/s (one, two or three continuous points) between two points.

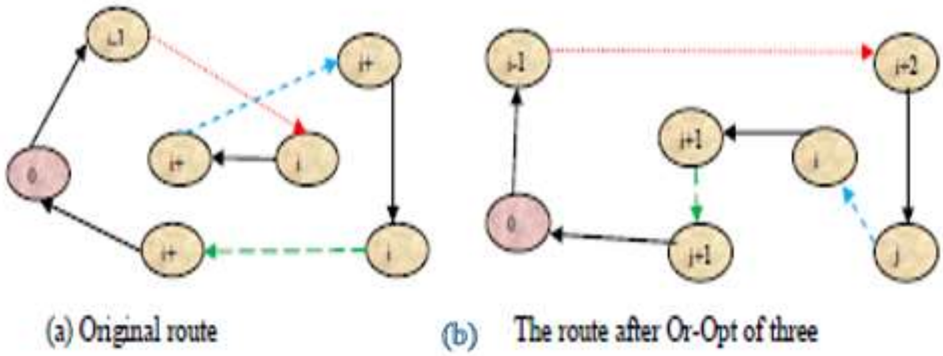

Figure 3 The Or-opt operator procedures (adapted from[38]

The relocate operator in Or-Opt algorithm works as if customer i is in route B= $(1, .. , i, i + 1 \ldots 1)$ and customer j is in route A $= (1, \ldots , j, j + 1 \ldots 1)$ removing customer i from route B (shirking of route B') to insert in to route A (expanding A') so as to get the new routes$B' = (1, .. , i - 1, i + 1..1)$ and $A' =$ $(1, \ldots , j, i, j + 1..1)$and the shrinking and expanding of routes continuous till no possibility is occurred due to constraints (capacity).

The standard Or-Opt[n] for n∈ (1,2,3) considers moving of n customers to another position of the same route (intra-route). One of the important contributions of V. Snyder's VRP solver is the possibility of applying Or-Opt (n) operators for inter route improvement. Applying improvement heuristic, however, the total cost of the Route distance (Rd) decreased from 810.04 kilometer to 780.9 kilometer and the vehicle utilization (Vu) in percentage increase from 76.6 to92 after 69 swap,7 2-Opt, 2 Or-Opt[1], 395 Or-Opt[2] and 222 Or-Opt[3] moves .

The number of route "number of vehicle" also reduced from six to five. With the same procedures for other nine instances, table 2 shows the comparison between the optimal solution, classical Clark and Wright method solution and proposed model solution of the study.

The comparison is in terms of solution quality (cost) and as it is clearly shown in the table for the value of CWVSPR (comparison between the classical Clark and Wright method and proposed approach) in column five each values are positive (in percentage) and indicates that the proposed model outperforms the classical CW method.

While the values given in column six are comparison, values for proposed model (PR) and the optimal solution by author (Opt). The negative sign given in column six indicates the deviation of proposed. Solution from the optimal one

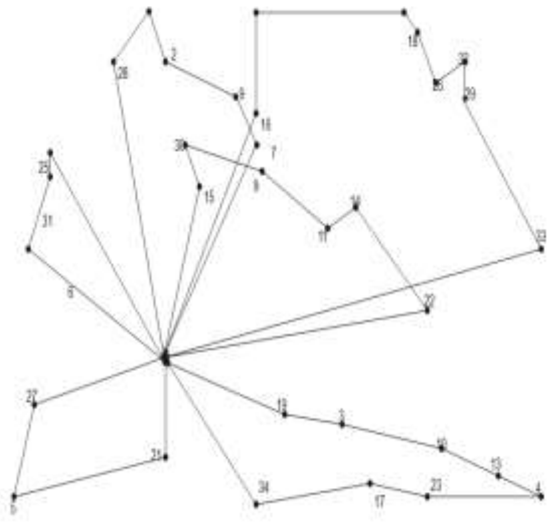

Figure 4 (a) Initial solution routes for A-n34k5 instance

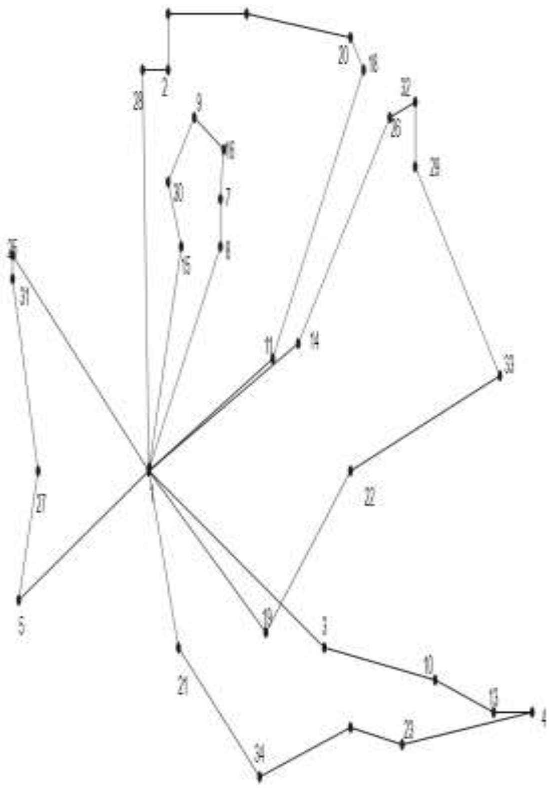

Figure 6 (b) Improved solution routes for A-n34k5 Instance

Possible to say almost all values, in column six are below one and this indicates the performance of the application of the local search is to some extent inevitable and would bring a solution approximately near to the optimal one. In all cases the vehicle capacity is 100 cubic meter. $\text{CWVSPR} = \frac{(V_{CW} - V_{PR})}{V_{CW}} * 100\%$, and $\text{PRVSOpt} = \frac{(V_{Opt} - V_{PR})}{V_{Opt}} * 100\%$.

Results and Discussion

The daily waste generation rate of the Addis Ababa city is 0.4kg per capita per day [40] and there is only open dumping site called "Repi or Koshe located 13 km away from the city center and vehicle (truck) from the various residential zones hauling the wastes to the dumping site.
The compactor truck is expected to make a maximum of two to three trips per day with a capacity of caring 27000 kg per a trip.

There are about 668 collection points in the city and found in scattered manner as depicted in figure 8. The compactor has to visit different collection points until it gets fully loaded. In the current collection process however, there is no any clearly defined routing for a vehicle where to start and end for a trip. On the other hand, the planned amount to be collected for 2014/15 was 497,264.562 ton and only 311,844.303ton collected which is 62.71% of the plan.

The case sub city selected for this problem, Arada sub city, has a total of 474.3cubicmeter solid waste was collected through seven trips each. Each of the vehicles has to be returned to the depot and the distance from the landfill to the depot is 6.06 km i.e., a total distance of 61.92 km per day.

The annual average vehicle utilization is 68.65% with the total distance coverage of 23290.513km per year.

The stochastic recyclable fraction (SRF) of the stochastic overall waste generation rate (SOWG)[41] method followed to consider dynamic nature of the case study. A one year collection points monthly generation rate with mean of 15.4 and 11.00 standard deviation guarantee (With a value of $p = 0.005$) the distribution of solid waste generation of each collection point is a triangular distribution with a value of $a = 5.5, \mu = 14 \text{ and } b = 40.5$.

The test result of the analyzed data for normal distribution gives a good fit of each point but with a p value of 0.009, the less the p value the less the chance of being uncertain. The analytical stochastic recyclable fraction described as equation 4 for probability distribution $f(X)$ of SRF and cumulative distribution function (CDF) $F(x)$.

$$f(X) = \begin{cases} (x-a), & if\ a \le X \le \mu \\ (b-x) & if\ \mu \le X \le b \end{cases} \quad (4.1a)$$

$$\begin{cases} \int_a^X f(x-a)d_x \quad if\ a \le X \le \mu \\ \int_x^b f(b-x)d_x \quad if\ \mu \le X \le b \end{cases} \quad (4.1b)$$

$$= \begin{cases} a+\sqrt{2u} & if\ a \le x \le \mu \\ b-\sqrt{2-2u} & if\ \mu \le X \le b \end{cases} \quad (4.1c)$$

A random number generated between zero and one (0, 1) for the value of $u = F(X)$ to generate the value of SRF =x based on equation 4.1c gives a distribution of figure 7 and the daily solid waste generation 497.26 cubic meters after five years.

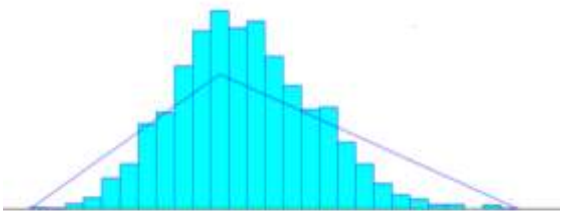

Figure 7 Distribution of solid waste generation

City of Addis Ababa located at 9°1′48″N38°44′24″E Coordinates and Arada sub city geographically located between 9°2′9.6″Nand 38°45′8.28″E and the longitudinal and latitudinal point of each -collection point determined from both Google earth and Google map engines.

Table 1 solution for A-n34-K5 *instance based on CW and Improvement heuristics*

Route	Clark and Wright (CW)				Improvement heuristics (IH)			
	Sequence	RC	RD	VU (%)	Sequence	RC	RD	VU (%)
1	**1**-34-17-23-4-13-10-3-19-**1**	92	165.9	92	**1**-2-5-31-6-27-5-**1**	89	146.5	89
2	**1**-27-5-21-**1**	48	77.59	48	**1**-8-7-16-9-30-15-**1**	86	102.14	86
3	**1**-6-31-25-**1**	54	92.45	54	**1**-11-18-20-1-24-2-28-**1**	93	176.42	93
4	**1**-7-9-2-24-28-**1**	99	131.09	99	**1**-21-34-17-23-4-13-10-3-**1**	96	166.88	96
5	**1**-33-29-32-26-18-20-12-16-**1**	100	209.06	100	**1**-19-22-33-29-32-26-14-**1**	96	188.96	96
6	**1**-15-30-8-11-14-22**1**	67	134.32	67	-			
Total		460	810.41		-	460	780.9	
Average		**76.67**	135.067	**76.6%**		92	156.18	**92%**

A Cartesian coordinates known as Geocentric coordinate used to determine the x, y coordinate of each collection point.

$$x = R.cos(LAT).cos(LON) \qquad (4.2a)$$

$$y = R.cos(LAT).sin(LON) \qquad (4.2b)$$

A Euclidean distance measure followed and the distance matrix obtained using the formula

$$d_{ij} = \sqrt{\left(x_i - x_j\right)^2 + \left(y_i - y_j\right)^2}.$$

Using equation 4. 2 the coordinate of the 31 collection, the depot and location of the landfill determined (figure 9). The direct graph mathematical model from equation 3.1-to 3.12 then treated for the value of V=n=1 the depot, V= 2 (32)

Table 3 gives the solution for the problem and the total travel distance of 45.1 kilometer per day confirmed. this solution is obtained after performing of 12 times three collection points, 23 times two collection points and 5 time one collection point relocation by using the Or-Opt move operation and two time 2-Opt as well as a six time exchange of customers between two route by swap operator. The total time to compute this solution is about 0.09 second with a building time of .00 second on the VRP solver of version 1.3. Based on the data obtained from the case company the minimum and maximum trip a compactor should make respectively is two and three and there are four compactor vehicles. The average-loading time in each collection point estimated to be15 minutes while the time for unloading at the landfill is 7 minutes.

The working hour per a day is 18 hour and the speed of the compactor is restricted to 40km per hour. Based on this input, the proposed solution guarantees a total time of 8.88 hours and makes us chanceful to assign one vehicle for more routs keeping the maximum trip. Hence, if the plan is to work with a maximum trip per a day, only two vehicles required and three vehicles are sufficient to work at a minimum trip plan. , Total distance covered for the existing system for one-day eight trip was 61.92 kilometer.

Using the Clark and Wright (CW) the total distance reduced to 52.7-km which is an improvement by 14.87% extend the model to the implementation of improvement heuristics (IH), the model gives a total distance of route per day 45.14 kilometer, a 27.385% improvement of the daily distance of the existing system.

Table 1 Comparison of the model

Instance (A)	CW	(PR)	(Opt)	CWVSPR (%)	PR VS Opt (%)
A-n32-k5	842	787.08	784	6.523	-0.393
A-n33-k5	713	662.1	661	7.139	-0.166
A-n33-k6	775	735.78	742	5.061	**0.838**
A-n34-k5	810.4	780.94	778	3.635	-0.378
A-n36-k5	826	814	799	1.489	-1.840
A-n37-k5	705	672	669	4.681	-0.448
A-n37-k6	975	950.6	949	2.503	-0.169
A-n37-k6	765	730.5	730	4.510	-0.068
A-n39-k5	898	821.7	822	8.497	0.036
A-n39-k6	861	833.4	831	3.206	-0.289
A-n44-k6	974	937.8	937	3.717	-0.085
A-n45-k6	1005	946	944	5.871	-0.212
A-n45-k7	1200	1145.3	1146	4.558	0.061
A-n46-k7	940	915.6	914	2.596	-0.175
A-n48-k7	1110	1074.1	1073	3.234	-0.103
A-n53-k7	1098	1011.8	1010	7.851	-0.178
A-n54-k7	1199	1169.2	1167	2.485	-0.189
A-n55-k9	1098	1075.1	1073	2.086	-0.196
A-n60-k9	1416	1354.8	1354	4.322	-0.059
A-n61-k9	1099	1035.7	1034	5.760	-0.164
A-n62-k8	1346	1289.1	1288	4.227	-0.085
A-n63-k9	1684	1617.1	1616	3.973	-0.068
A-n63-k10	1352	135.2	1314	2.722	-0.091
A-n64-k9	1489	1403.2	1401	5.762	-0.157
A-n65-k9	1230	1175.2	1174	4.455	-0.102
A-n69-k9	1206	1161.3	1159	3.706	-0.198
A-n80-k10	1859	1777.05	1763	4.408	-0.797

On the other hand, there were seven routes for the existing system with route capacity of each between 61.05 and 71.69 cubic meter of solid waste, which yield a daily average of 68.19 cubic meters per a route. However, the route capacity for the proposed model varies between 91.65and 100.00 cubic meters. Based on the design capacity of the compactor's which 100cubic meter, the daily utilization of Vehicle for the existing system is 68.19 % while in the proposed model 95.466%.

Table 2 Optimal route and route utilization

Route	Collection points	Rc (m^3)	VU	Rd (km)
1	**1**-6-16-26-29-30-27-**33**	97.06	97.06%	10.68
2	**1**-7-9-12-10-**33**	100	100%	8.38
3	**1**-8-28-25-5-32-**33**	95.02	95.02%	7.95
4	**1**-14-15-23-18-2-17-22-**33**	91.65	91.65%	8.74
5	**1**-20-24-31-4-21-11-19-13-**33**	93.60	93.60%	9.39
Total		477.33		45.14
Average		95.466	95.466%	9.028

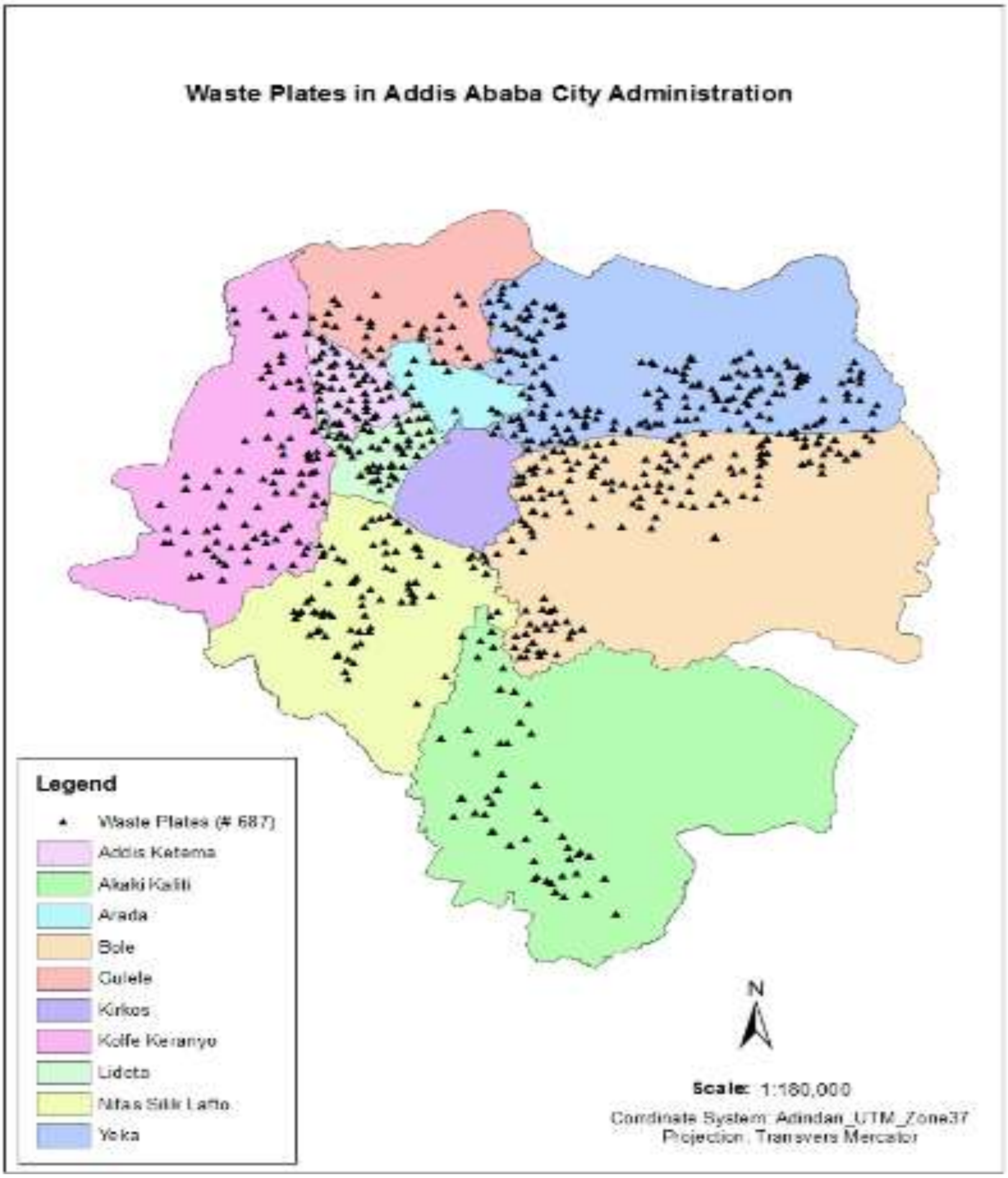

Figure 8 Distribution of the waste collection points in each sub city

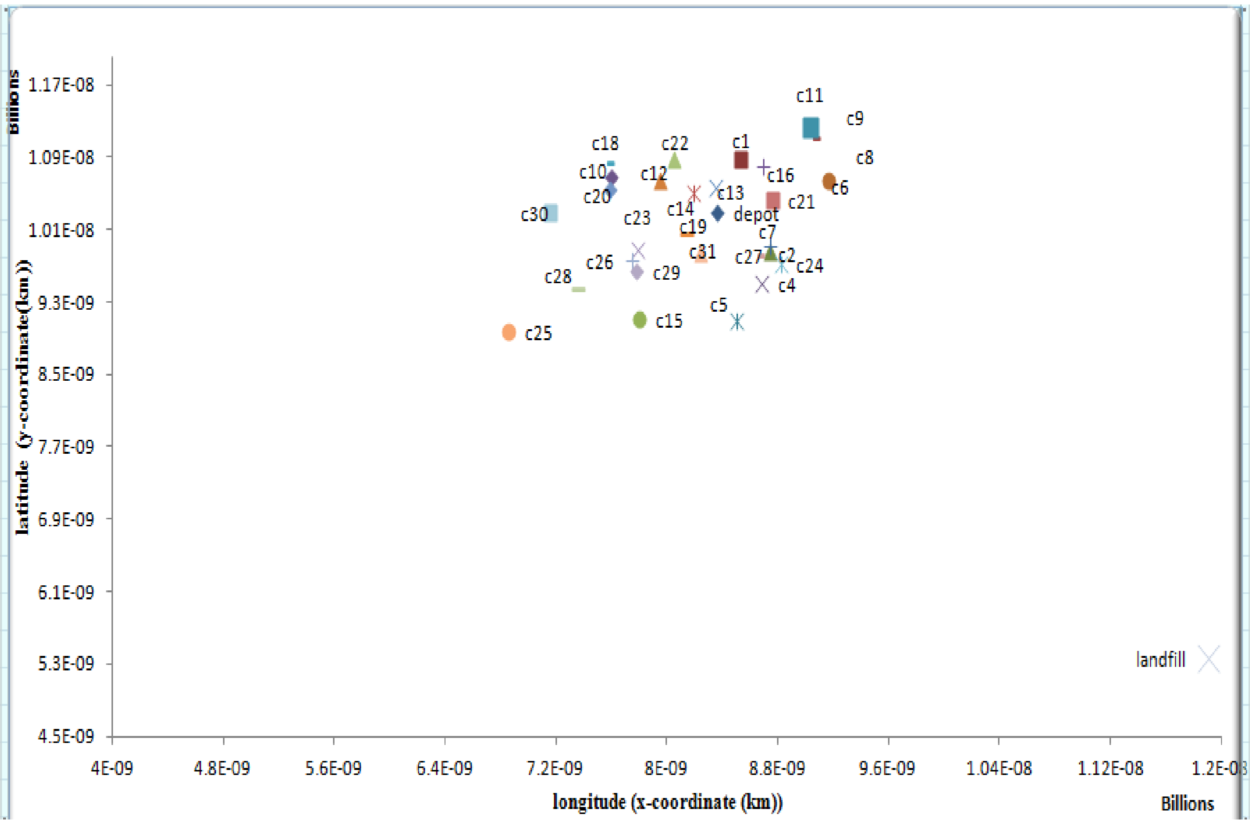

Figure 9 x, y coordinates of the depot, collection points and landfill (km)

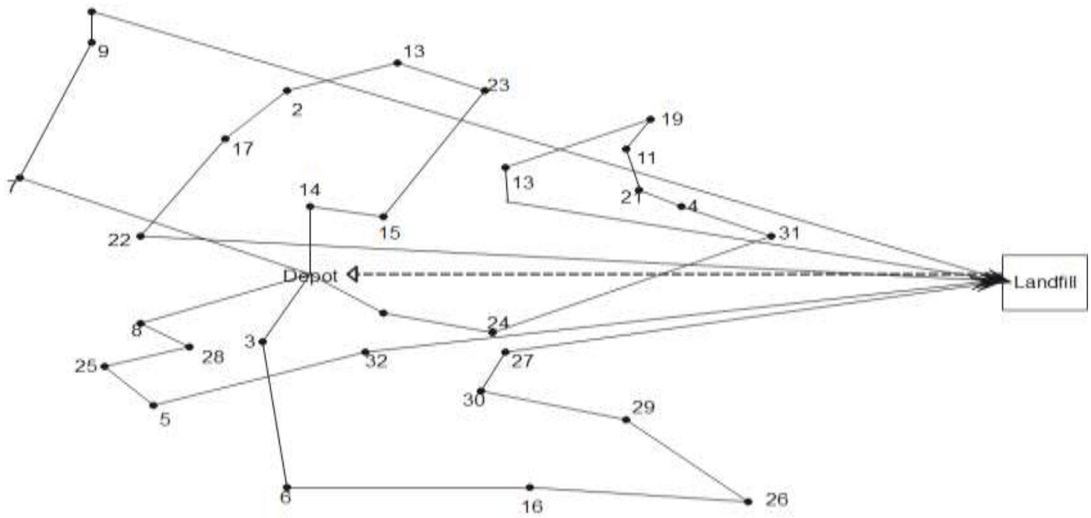

Figure 10 Final route of the waste collection problem in Arada Sub City

Conclusion and Future work

As part of a city logistic problem, the waste collection process considered as both facility location and a vehicle routing problems. The latter emphasized here and the node routing problem with a capacitated vehicle routing problem modeled using mixed integer programming to obtain an optimum distance. Bench marking problem instance used to verify the solution approach, 2-opt and Or-Opt improvement heuristics applied and a remarkable solution obtained. Based on the proposed model the distance that a collection vehicle could cover is about 16430km and guarantees a saving of about 29.45% over the existing system and the utilization of vehicle in a route increases in average from 68.19% for the existing system to 95.5 % by the model.

With the support of the result, we are on the position to conclude that classical algorithms are sufficient, if managed well, in solving problem of interest and important implication of the result however, implies the need of redesigning to case problem.

Finally, an integrated municipal solid waste management system based on multi-criteria decision analysis recommended from the solid waste management perspective, more importantly considering the problem at stochastic nature with the help of deploying sophisticated metaheuristic algorithm are future interest of the problem domain.

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