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A Simulated Annealing Algorithm for Solving the School Bus Routing Problem: A Case Study of Dar es Salaam

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Abstract

School bus routing is one of major problems facing many schools because student's transportation system needs to efficient, safe and reliable. Because of this, the school bus routing problem (SBRP) has continued to receive considerable attention in the literature over the years. In short, SBRP seeks to plan an efficient schedule for a fleet of school buses where each bus picks up students from various bus stops and delivers them to their designated school while satisfying various constraints such as the maximum capacity of a bus, the maximum transport cost, the maximum travelling time of students in buses, and the time window to reach at school. Since school bus routing problems differ from one school to another, this paper aims to developing Simulated Annealing (SA) heuristic algorithms for solving formulating a mathematical model for solving the student bus routing problem. The objective of the model is to minimize amount of time students in the buses from the point where they pickup to the school. We illustrate the developed model using data from four schools located at Dar es salaam, Tanzania. We present a summary of results which indicates good performance of the model.

Keywords: bus stop, students, bus, simulated Annealing (SA), Objective function value, Current route, proposed route.

1. Introduction

The School Bus Routing Problem (SBRP) seeks to plan an efficient schedule for a fleet of school buses that pick up students from various bus stops and deliver them to the school by satisfying various constraints, such as the bus capacity, all pupils are picked, etc. Roughly, in the SPBP problem there is a set of fleet of buses serving a school, a set of routes, a set of bus stops, the number of students at each stop and the time matrix. Each bus has a route to transporting students during morning time by takes students from pick-up points and delivers them to school also reversed this route during afternoon by transporting students from school and derivers them to bus stop nearly to their home. The set of stops is consists of points where students are pick-up the time matrix gives the time required to move one stop to another. The main task in SBRP is to assigned buses into pick-up points and scheduled routing of a bus in order to minimize amount of time students spent in the buses to reach at school.

The bus routing problem varies among schools. For example, Schittekat et al., (2012) reports that in some countries, students living within a certain distance to school are entitled by law free transportation to and from school. A bus stop should be located at a maximum distance from home of each student (e.g. 750m). Hence a set of potential bus stops is predefined in advance, from hierarchical point of view; one has to first select the bus stops and assign the students to the bus stops and then defined the routes for the buses.

SBRP has received considerable attention among researchers since it was introduced by Newton and Thomas (1969). Below we present a brief survey on previous researches. Clearly, the school bus routing problem is a generalization of the basic vehicle routing problem and therefore also is NP- hard problem (see, e.g., Schittekat et al., 2013). A list of works on SBRP includes: Desrosier et al. (1981), Swersey and Ballard (1984), Bowerman, et al., (1995), Spasovic et al, (2001), Li and Fu (2002), Anderson et al, (2005), Schittekat et al., (2006), Park and Kim (2010), Arias-Rojas et al., (2012), Taehyeong and Bum, (2013), and Ngonyani, (2013)

The NP-hardness of SBRP implies that it is very unlikely that the SBRB problem can be solved in polynomial time. Therefore, researchers have explored the possibility of finding efficient algorithms that give good approximate solutions. Many researchers have used heuristics algorithms for solving SBRP with large instances. Corberan et al (2002) adapted Scatter Search (SS). Other researchers used Simulated Annealing (SA) and Tabu Search (TS) to improve initial solution for SBRP generated by insertion based heuristic (Ripplinger, 2005; Pacheco and Marti, 2006). Recently, Arias-Rojas et al (2012) used the Ant Colony Optimization, and Ngonyani (2013) applied Tabu search based heuristic to the problem. This work presents a Simulated Annealing approach to solve SBRP, a case study of schools in Dar es Salaam. Simulated annealing is a popular local search meta-heuristic used mainly to solve discrete and -to lesser extent continuous-optimization problems Henderson et al (2003).

Simulated annealing (SA) is a stochastic optimization technique introduced by Kirkpatrick in 1983. Like other Meta-Heuristics, SA starts from an initial solution and search solution space iteratively to improve the current solution. The key feature of SA is that it escapes local optima by allowing hill-climbing moves (i.e., moves which worsen the objective function value) hoping that it will find a global optimum. At a given iteration, the algorithm randomly generates a new solution in the neighborhood of the current solution. This new solution is evaluated and compared with the previous solution. If the solution from the new solution is better than the previous one, it is accepted. SA also accepts a non-improving neighbouring solution with a given probability that decreases as the search progresses. A survey on the areas in which SA has been applied can be found in Henderson et al (2003).

In this work an SA based heuristic was implemented using Borland C++ 4.5 programming language using real data. We collected the data from four schools which allocated at Dar es salaam, Tanzania and validated in a program for the solution. We compare the value of objective function for a current route and value of objective function for a proposed route, the aims is to get saved time in proposed route. Since the proposed route reduced travelling time for the students within a bus at all bus stops compare to current route, we suggested this route to be used by school in order to minimize total travel time spent by students within the bus in all bus stops to reach a school.

The remainder of the paper is organized as follows. We first present the student transport situation in Dar es Salaam, giving the main characteristics the problem. Then we give the formulation of the problem, followed by implementations of the proposed solution. Finally, we give a summary of results and conclusions.

2. Student Transport Situation in Dar es Salaam

Dar es Salaam region is one of Tanzania 30 administration re Dar es Salaam region is one of Tanzania 30 administration region. It is the largest in Tanzania, and Kumar and Barret (2008) report that Dar es Salaam is among the rapid growing cities in Africa. Accordingly to the 2012 national census, the regional had a population of 4,364,541 which was much higher than the pre-census projection of 3,270,255; the region 5.6 percent average annual population growth rate was the highest in the country. It was also the most densely populated region with 3,133 people per square kilometer. The most common form of transport in Dar es Salaam is public buses called daladala which are often found at the many bus terminals. (Census Report, 2012)

The student transport in Dar es Salaam is currently a big problem that faces primary and secondary students in Dar es Salaam city during the morning and evening where they are encountering various issues from daladala (bus) operators and as a result, students reach their schools late. Masozi Nyirenda reported in the Guardian Newspaper of 9th July 2012 that inadequate and unreliable transport for students in various cities and towns in Tanzania has been one of the chronic problems. This hinders students' academic progress. In addition, the student transportation problem causes some other social problems such as poor academic performance, teen pregnancies and other delinquencies such as students fighting with daladala conductors.

The school bus scheduling in Dar es Salaam is a challenge problem in many private schools, which provides the transport to their students. In a school there are buses which picked up students at pick-up points and deliver them to their school. The school management scheduled the bus routing by considering the number of pick-up points, number of students at the pick-up points, number of buses which are available to the school, travelling time between the bus stops and distance between the stops. Each school bus has a specific one route during the morning session for transporting students from pick-up points and delivers them to school, and reversed this route during afternoon for transporting students from school to stops nearly their home. The available stops are generated, students are assigned to the stops, and the bus is assigned to stops in their existing route. The school bus conductor scheduled the bus routing by take first bus and gives the stops with student required to picked by that bus and deliver them to school, take second bus gives the stops which not visited by previous bus with students required to picked by that bus and deliver them to school. This action is continue up to last bus, the conductor uses experienced how to known the all area that can generates routes connecting the pick-up points and ends to school, the conductor uses locally techniques to schedule the bus routing this arise in the route students to spend more time within the bus than expected to reach at school and home during school day. Unfortunately, most of school which provides the transport service to their students is lacking scientific methods that can be used to route and schedule these school buses. This leads students spend much more travelling time than expected to reach at school and home.

3. Presentation of the problem

The discussion in this section is also presented in Manumbu et al., (2014), and summarized here for clarity of presentation.

Model Assumptions:

1. Each bus has only one route for transporting students to school.
2. The pick- up points visited and picked students by bus are scattered and not necessary to be linearly ordered.
3. If the bus visiting a point it must picks up all students at that point.
4. The time spend by students within the bus from one pick up point to another includes jams, road condition, accident action and waiting time in traffic light.
5. Each pick up point is allocated to only one bus.
6. Each bus has only one route for transporting students to school in the morning and back to their home after classes.
7. Each school bus picks up students at least on one pick- up point.

Model Objective

The objective of the model is therefore to plan routes that will minimize the total travel time spent by students in all bus stops by using the non- linear mixed integer programming model.

Sets: The following are the sets that are used in the model formulation.

1. $S = \{1, 2, \dots, N\}$ a set of all bus stops where one or more students are picked up whereby N is the total number of stops arranged scattered around the school and $N+1$ denotes the school.
2. $K = \{1, 2, 3, \dots, B\}$ a set of the available buses to be used where B is the total number of available buses.

Parameters: Proposed model uses the following parameters;

1. B represents the number of available buses for the school bus service.
2. T_{ij} represents the travel time from $i \in S$ to $j \in S$.
3. N is the total number of bus stops available
4. C_b denotes the capacity of bus $b \in K$
5. α is the average pick – up time of one student by bus at a pick-up point.
6. Y_i is the number of students at stop $i \in S$
7. Z_b is the set of pick-up point to be visited by bus $b \in K$
8. S_{bi} is represents the index number of pick-up point be visited by bus $b \in K$

The mathematical model to represent the problem is:

$$minimize\ f = \sum_{b=1}^{B}\{\sum_{i=1}^{|Z_b|}(T_{S_{bi},S_{b(i+1)}}(\sum_{l=1}^{i} Y_{S_{bl}}) + \alpha Y_{S_{bi}}(1 + \sum_{l=1}^{i-1} Y_{S_{bl}}))\}$$

Subject to;

$$\sum_{i=1}^{|Z_b|} Y_{S_{bi}} \leq C_b\ , \quad b = 1,2,\dots,B$$

(1)

$$.S_{b(|Z_b|+1)} = N + 1,\ \ b = 1,2,\dots,B \qquad (2)$$

$$\sum_{i=1}^{N} Y_i = \sum_{b=1}^{B} \sum_{i=1}^{|Z_b|} Y_{S_{bi}} \qquad (3)$$

$$Y_i \geq 0\ and\ an\ integer \qquad (4)$$

Constraints, (1) ensures that the sum of students picked up in all points by bus must not exceed the bus capacity; (2) ensures that all buses finished their routes at a school; (3) ensures that all students are picked up; (4) the number of students at each bus stop is nonnegative.

4. Implementation of Simulated Annealing Algorithm for SBRP

Simulated Annealing (SA) is a probabilistic meta-heurist algorithm. It has been devised so as to avoid being trapped in poor local optima by accepting bad moves according to a probability function. The method initiates the physical annealing process in metallurgy; starting from a randomly generated solution, a neighbouring solution is sampled and compared with the current one according to an appropriate probability function. The acceptance and rejection of the worse move is controlled by a probability function. The probability of accepting a move, which causes an increased Δ in objective function f, is called the acceptance function. The acceptance function is normally set to $e^{-\frac{\Delta}{T}}$, where T is a control parameter, which corresponds to the temperature in analogy with the physical annealing. This acceptance function implies that the small increase in objective function f is more likely to be accepted than a large increase in objective function f. When T high most uphill moves are accepted, but as T approaches to zero, most uphill moves will be rejected. Therefore Simulated Annealing (SA) starts with a high temperature to avoid being trapped in poor local optimal, the algorithm proceeds by attempting a certain number of moves at each temperature and decreased the temperature. Thus, the configuration decisions in SA proceeds in a logical order. The heuristic terminates when either the better minimal solution is obtained or the initial temperature decreases to the lowest one (called *freezing point*).A pseudocode for Simulated Annealing for this work is given in Figure 1**.**

```
Input: Initial Feasible Solution $S_0$
Initialize: $T = T_0$, Freeze
While ($T > Freeze$){
        Get a candidate solution $S \in N(S_0)$
        If S is feasible    {
            $\Delta = f(S) - f(S_0)$
            If $\Delta < 0$
                $S_0 = S$
          Else   {
                Generate a random $x \in (0,1)$
                If $(x < e^{-\frac{\Delta}{T}})$
                                $S_0 = S$
                Else
                                Reject $S$
             }
        }
           decrese $T$
}
```

Figure 1: Pseudocode for the Simulated Annealing heuristic.

For effective application of the Simulated Annealing heuristic an initial solution, an appropriate neighbourhood, a good initial temperature, an effective decreasing rate for the temperature and stopping criteria have to be specified

a) The initial solution

One way of obtaining an initial solution is to generate a feasible solution randomly, see, e.g. Suman et al (2006) and Woch et al (2009). This method has a disadvantage that a randomly generated solution can be very far from the optimal solution; hence much iteration will be required to reach the solution. The since the main purpose of this work is to improve an existing system, we have used a current (manual generated) solution as the input initial solution.

.

b) The neighborhood selection

The way in which SA moves from one solution to its neighbour is another critical component of the algorithm implementation. In SBRP, 2-opt, 1-1 opt and 1-0 exchange are possible moves for a neighbourhood (see Ngonyani 2013). In this work we random a new solution from the current solutions as follows:

i. Select a random a bus stop s the set of all possible bus stops.

ii. Let student in the stop s be picked by bus b.
iii. Select a random bus$b' \in B - \{b\}$, where B is the set of all buses.
iv. Move the stop s to from b to b'.

c) The initial value of temperature (T)

The initial temperature is vital factor to the success of the algorithm. If the value of the starting temperature gets too big, SA converge very slow convergence and in general, the optimization process degenerates to a random walk. On other hand, if the initial temperature is small then there is a greater probability of converging to local minima. Various methods for finding the appropriate starting temperature have been developed. Aarts et al (1988) proposed a method to select the initial temperature based on the initial acceptance ratio X_0, and the average increase in the objective function, $\Delta \mathrm{f}_0$: $\mathrm{T} = -\frac{\Delta \mathrm{f}_0}{\ln(\mathrm{X}_0)}$ where X_0 is defined as the number of accepted bad moves divided by the number of attempted bad moves. Dowsland (1995) introduced various methods for finding the appropriate starting temperature. In this work we set the initial temperature to 100; higher temperature values did not show any improvement on the final solution

.d) The cooling schedule

The performance of the SA algorithm depends on the rate at which the temperature is reduced. Lundy and Mees (1986) suggested the following rule to generate the temperature sequence

$$T(i) = \frac{T(i)}{1+\alpha T(i)}, 0 < \alpha < 1$$

The most common widely used method involves the geometric reduction function$T(i) = \alpha T(i)$, where $i = 0,1,2, \ldots, T(0)$ is the initial temperature and α is a temperature factor that is a constant between 0 and 1. Experience has shown that should be between 0.8 and 0.99, Pham and Karaboga (2000).

e) The stopping criterion to terminate the algorithm

It is usual to let the temperature decrease until it reaches zero However, this can make the algorithm run for a lot longer. Therefore, the stopping criteria can either be a suitably low temperature or no changes in the solution for a number of iteration (i.e. no better or worse moves are being accepted for a number of iterations). In our study the Simulated Annealing Algorithm stopped at final iteration when final temperature $\mathrm{T} = 0.00001$ or if the algorithm runs for 200 iterations without any change in the solution.

5 Experimental and Result Analyses

The algorithm was tested on data taken from four schools in Dar es Salaam, Tanzania. The schools are Atlas primary school, African nursery and primary school, Yemen Secondary School and Sahara Nursery and Primary School. The algorithm was implemented using Borland C++ Version 4.5. We ran the algorithm on a 2GHz machine with 1.87 GB RAM and Windows 7. The size of the is given in Table 1.

Table 1: Size of input data

School	Number of Buses	Number of Bus Stops	Number of Students
Atlas PS	9	68	445
African N&PS	7	65	197
Yemen SS	5	39	113
Sahara N&PS	3	27	95

The parameters of simulated annealing are given in Table 2.

Table 2: Parameters for Simulated Annealing

Parameter	Value
Cooling rate (α)	0.98
Initial Temperature (T_0)	100
Freezing Temperature $(Freeze)$	0.00001

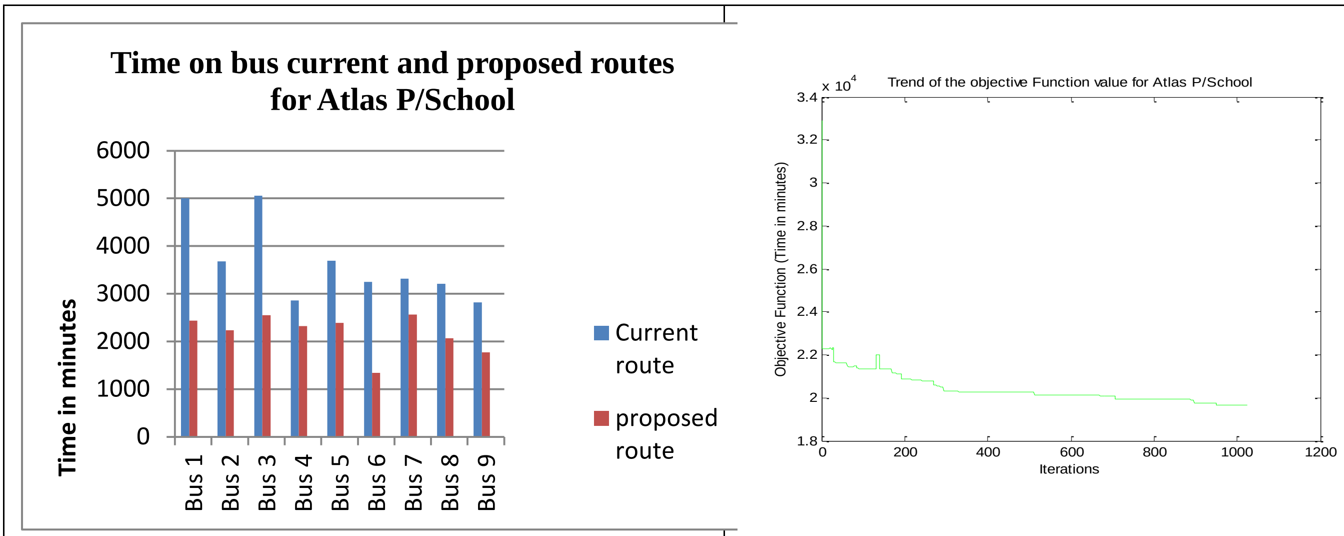
Results at Atlas Primary School

As indicated in Table 1, this school has 9 buses, where each bus served 1 route. Table 3 shows the current route of each bus in manual generated solution and proposed solution after the implementation of SA. The table shows a significant amount of time is saved by each bus after the implementation of the algorithm. As an example, consider Bus 1. At the current implementation, the students spent 5004.5 minutes in this bus. After the implementation of the algorithm the time spent by students in this is reduced to 2233.5 minutes. Thus, the proposed implementation results in reduction of students' travelling time by 55.37% in this bus. The similar trend is observed in remaining buses in the school. Combining all buses, we see that total amount of time spent by student in all buses is reduced from 32883.5 to 19669.5, which is about 40.2% saving. Figure 2(a) gives a comparison of time spent by students in each bus between current manual solution and the proposed computer solution.

Table 3: Discussed results, in current routes before and proposed routes after Simulated Annealing Algorithm implementation for Atlas Primary School.

Current Implementation			**Proposed route after SA implementation**		
Bus	Route	Time	Bus	Route	Time
Bus 1	46,65,29,10,31,48,67,2,S	5004.5	Bus 1	67,29,10,31,48,65,14,S	2433.5
Bus 2	23,40,58,22,3,57,39,68,S	3680.5	Bus 2	54,68,22,58,57,3,50,S	2233
Bus 3	49,32,1,30,12,66,47,4,59,S	5058	Bus 3	64,32,40,66,4,12,30,1,26,S	2553.5
Bus 4	41,24,7,44,63,15,33,50,S	2862	Bus 4	23,6,63,33,15,44,24,41,S	2319.5
Bus 5	5,26,43,61,42,25,S	3693	Bus 5	55,25,52,42,56,61,2,5,S	2390.5
Bus 6	56,38,21,35,52,17,9,S	3246.5	Bus 6	49,9,59,38,17,43,S	1337.5
Bus 7	64,45,28,11,53,36,19,55,62,S	3314.5	Bus 7	62,19,45,28,11,53,47,46,8,S	2565.5
Bus 8	60,8,37,14,51,20,S	3205.5	Bus 8	21,35,51,20,37,60,S	2065
Bus 9	13,34,16,27,18,54,6,S	2819	Bus 9	36,39,13,27,16,18,34,7,S	1771.5
		f =32883.5			f =19669.5

Figure 2(b) gives the trend of the improvements in the objective function by iterations for Atlas Primary School. Clearly, the graph shows that there is a sharp drop in the objective function for in first little iteration followed by a slow convergence. This observation suggests that a manual prepared solution is far from the optimal, hence the proposed solution will improve significant the system.



(a) : Current and Proposed routes of 9 buses for Atlas PS

(b) : Trend of objective function values for Atlas PS

Figure 2: Summary results for Atlas Primary School

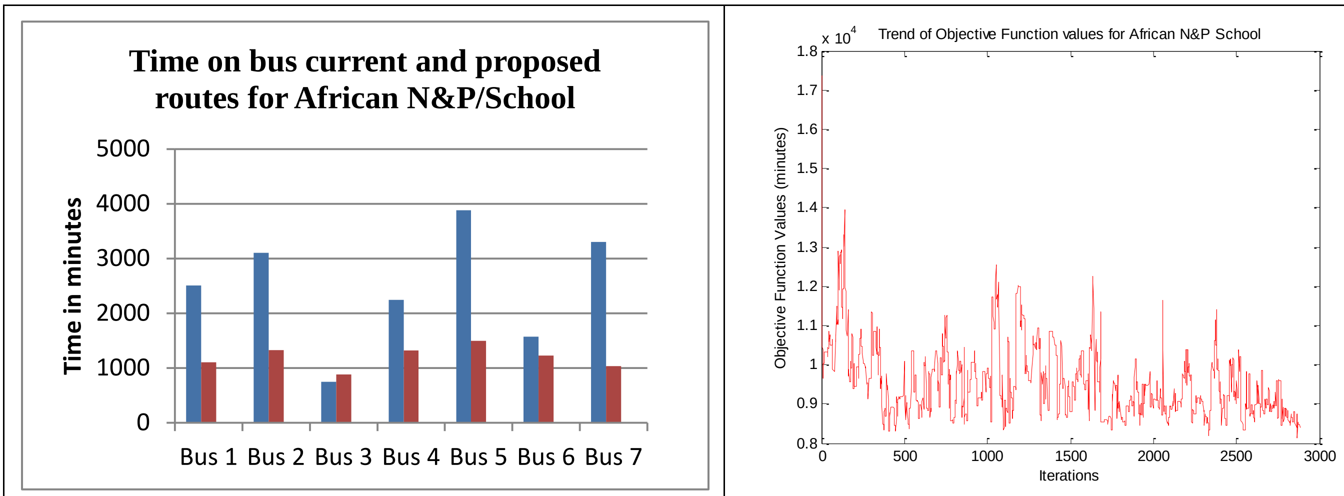
Results at African Nursery and Primary School

The school has 7 buses which pick-up students in 65 stops. A comparison solution before and after implementation our algorithm is given Table 4. From the table we observed that time spent by students in all 7 buses is significant reduced by the algorithm. For example, the time spent by students in Bus 5 is reduced from 3882 to 1497 minutes. This is about 61.44% time saving. For combined all 7 buses, total time is reduced from 17358.5 to 8385.5 minutes. Thus, this new proposed solution saved 8973 minutes (51.69%) compared to current routes.
Figure 3(a) gives a comparison of time spent by students in each bus between current manual solution and proposed computer solution.

Table 4: Results, in current routes before and proposed routes after Simulated Annealing Algorithm implementation for African Nursery and Primary School

School	Current route before SA implementation			Proposed route after SA implementation		
	Bus	Route	Time	Bus	Route	Time
African	Bus 1	12,28,46,63,1,20,38,55,14,32,S	2507	Bus 1	21,38,59,4,14,28,33,55,45,S	1103
N&PS	Bus 2	49,65,31,16,51,34,3,21,39,S	3101	Bus 2	49,18,8,51,13,3,43,31,16,S	1326
	Bus 3	6,23,41,58,15,33,50,48,S	749	Bus 3	17,54,41,64,58,20,65,25,36,S	880.5
	Bus 4	62,45,27,11,2,57,4,22,40,S	2243.5	Bus 4	10,6,63,19,62,11,57,23,35,26,S	1318.5
	Bus 5	60,43,25,8,42,7,24,59,5,S	3882	Bus 5	15,7,39,40,30,46,48,50,32,34,S	1497
	Bus 6	19,37,54,13,30,64,47,29,18,53,S	1571.5	Bus 6	53,29,47,24,22,9,27,42,60,S	1227.5
	Bus 7	61,9,44,26,36,52,17,35,10,56,S	3304.5	Bus 7	56,5,52,37,12,44,61,1,2,S	1033
			f =17358.5			f =8385.5

Figure 3(b) gives the trend of the improvement in the objective function by iterations for African Nursery and Primary School. The graph shows that there is a sharp drop in the objective function for in first little iteration followed by a slow divergence in next little iteration and then followed by slow convergence to last iteration. This observation suggests that a manual prepared solution is far from optimal, hence the proposed computer solution will improve significant the system.



(a) : Current and Proposed routes of 7 buses for African N& PS

(b) : Trend of objective function values for African N& PS

Figure 3: Summary results for African Nursery and Primary School

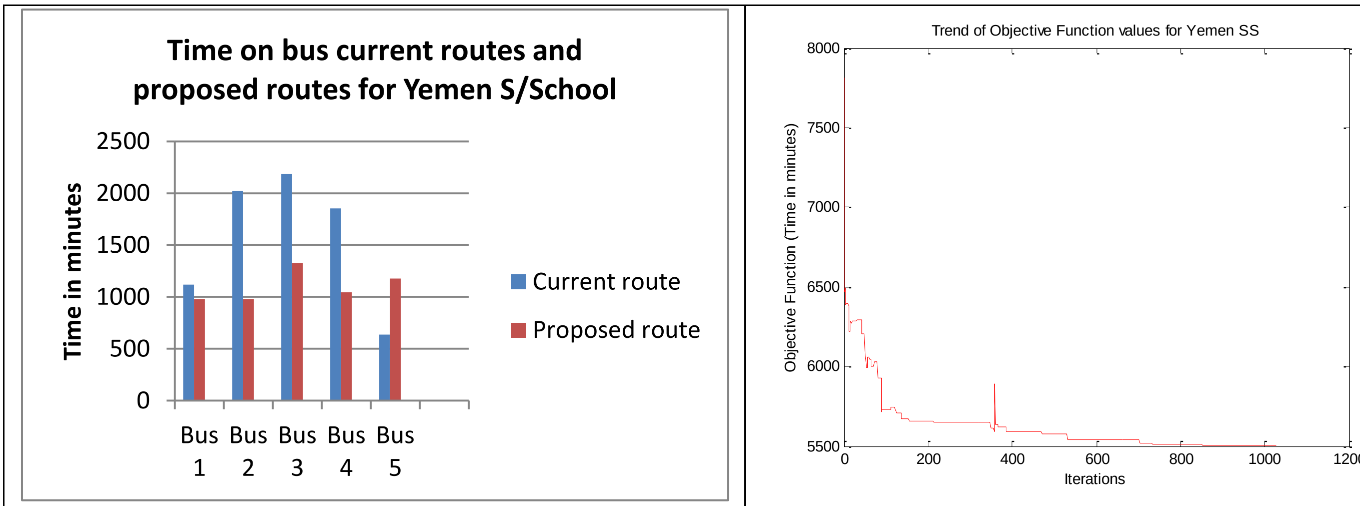
Results at Yemen Secondary School

This school has 5 buses which picked up students at 65 bus stops. Table 5 shows the comparison between manual generated solution and proposed computer solution. From this table we observed that time spent by students in same buses is reduced by algorithm. For example consider bus 2, the time spent reduced from 2021 to 978.5, this is 1042.5 saved time (51.58%) from current manual solution. For combined all 5 buses, total time reduced from 7814.5 to 5504 minutes, thus proposed routes for all 5 buses saved 2310.5 minutes (29.57%) compare to current routes. Figure 4(a) gives a comparison of time spent by students in each bus between current manual solution and proposed computer solution.

Table 5: Results, in current routes before and proposed routes after Simulated Annealing Algorithm implementation for Yemen Secondary School

School	Current route before SA implementation			Proposed route after SA implementation		
	Bus	Route	Time	Bus	Route	Time
Yemen SS	Bus 1	7,12,1,26,18,15,23,20,24,S	1119	Bus 1	12,23,15,18,1,13,24,21,5,S	979
	Bus 2	4,6,8,14,17,19,22,25,5,S	2021	Bus 2	29,14,17,8,19,22,S	978.5
	Bus 3	3,9,11,21,16,13,2,10,S	2183	Bus 3	20,7,26,16,11,9,3,27,2,S	1325
	Bus 4	31,38,29,36,32,34,30,39,27,S	1854	Bus 4	37,38,4,6,25,39,10,S	1044
	Bus 5	37,35,28,33,S	637.5	Bus 5	36,34,31,32,35,28,30,33,S	1177.5
			f =7814.5			f =5504

Figure 4(b) gives the trend of the improvement in the objective functions for Yemen Secondary School. Clearly, the graph shows that there is a sharp drop in the objective function for in first little iteration followed by slow convergence. This observation suggests that a manual prepared solution is far from optimal, hence the proposed computer solution will improve significant the system.



(a) : Current and Proposed routes of 5 buses for Yemen SS

(b): Trend of objective function values for Yemen SS

Figure 4: Summary results for Yemen Secondary School

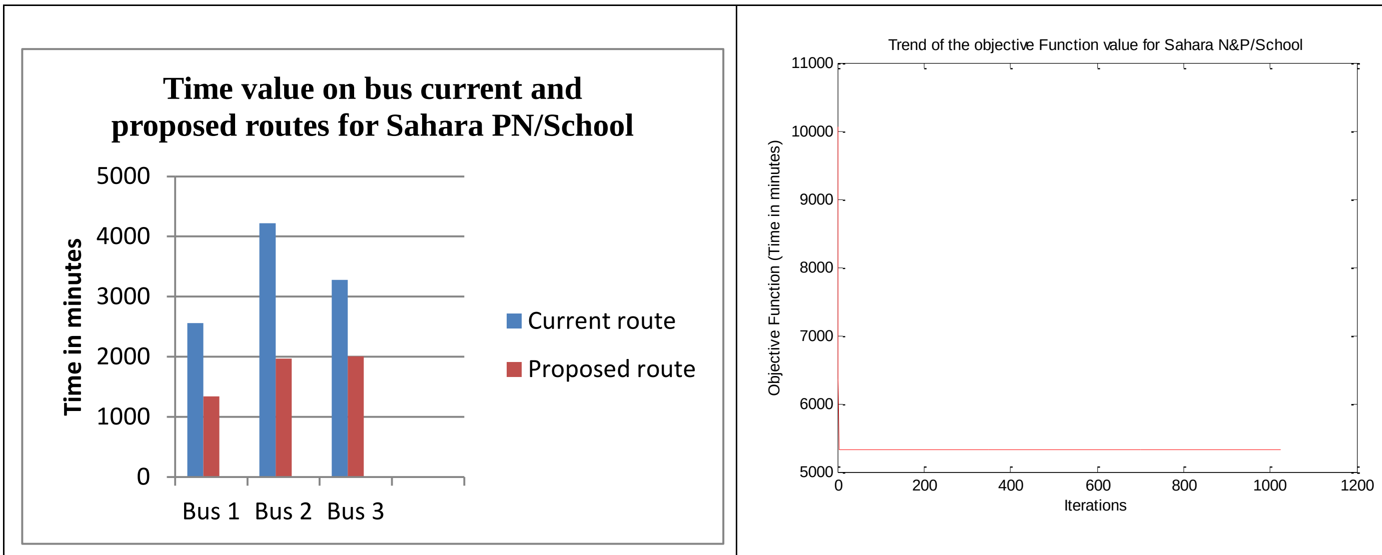
Results at Sahara Nursery and Primary School

This school has 3 buses which serviced 95 students from 27 bus stops. A comparison solution before and after implementation our Simulated Annealing Algorithm is given in table 6. From table 6 we observed that, time spent by students in all 3 buses is reduced by algorithm. For example, time spent in bus 2 reduced 4218.5 to 1967.5 minutes, so a proposed computer solution saved 2251 minutes (53.36%) compare to current manual solution. For combined all 3 buses, total time reduced from 10060.5 to 5317 minutes, thus proposed routes for all 3 buses saved 4743.5 (47.15%) compare to current routes. Figure 5(a) gives a comparison of time spent by students in each bus between current manual solution and proposed computer solution.

Table 6: Results, in current routes before and proposed routes after Simulated Annealing Algorithm implementation for Sahara Nursery and Primary School

School	Current route before SA implementation			Proposed route after SA implementation		
	Bus	Route	Time	Bus	Route	Time
Sahara N&PS	Bus 1	7,21,24,5,3,15,9,12,S	2562.5	Bus 1	24,21,3,9,12,15,13,7,5,S	1342.5
	Bus 2	1,11,14,26,18,20,23,16,4,S	4218.5	Bus 2	4,26,20,23,14,18,16,11,1,S	1967.5
	Bus 3	2,6,8,10,13,17,19,22,25,27,S	3279.5	Bus 3	19,10,17,22,27,25,2,6,8,S	2007
			f =10060.5			f =5317

Figure 5(b) gives the trend of the improvement in the objective function by iterations for Sahara Nursery and Primary School. The graph shows that there is a sharp drop in the objective function for in first little iteration followed by a constant convergence. This observation suggests that a manual prepared solution is far from optimal, hence the proposed computer solution will improve significant the system.



(a) : Current and Proposed routes of 3 buses for Sahara N&PS

(b) : Trend of objective function values for Sahara N&PS

Figure 5: Summary results for Sahara Nursery and Primary School

6. CONCLUSION AND FUTURE WORK

In this study, Simulated Annealing Algorithm is proposed to solve the mathematical model presented for the school bus routing problem. The model objective is to minimize the time spent by students within the bus at all pickup points to their school, since the model formulated to minimize the time so its combinatorial optimization problem. Simulated Annealing algorithm solved model, where a desired global minimum is hidden among many local minimum. These Simulated Annealing methods have attractive and it's faster to reach final solution compare with other optimization technique. The reasons that its attractive are, a solution does not get trapped in local minimum by sometimes it is accepted even the worse move and configuration decision proceed in a logical manner in simulated annealing. The paper provides pseudocode of Simulated Annealing for making a solution of presented mathematical mode, implementation of SA is shown clearly in this paper, also the SA algorithms should suggested to use to generate a larger set of optimal solutions giving a wider choice to the decision maker. The annealing schedule is the essential part of Simulated Annealing as help to determine the performance of the method. The good performance of this method is tested by data's input in the program for results, data's collected from five schools located in Dar es salaam, Tanzania. From analyses of the results it shows that the school management and students benefits by this study when should use proposed routes. The proposed routes reduce total time spent by students within the bus at all pickup points to their school compared to current routes. The Borland C++ 4.5 programming language used to write the codes for simulated annealing algorithm is simple to understand and if run it gives the better solution in a short time. In future the researchers should improve the quality of data collected by measure time from one stop to another not take approximation data from drivers and conductor of school buses, also should added the constraints in the model such as time windows and the buses to serves malt schools instead of single school. The intensive SA algorithm search must be developing in future time in order to improve the solution that converges near to optimal solutions. This lead SA algorithm to search faster along the optimal solutions of combinatorial optimization problem of SBRP

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