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Modeling and Analysis of Bus Scheduling Systems of Urban Public Bus Transport

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Abstract: **Anbessa City Bus Service Enterprise (ACBSE) is the only public enterprise that provides transport services in and around the city of Addis Ababa. The enterprise uses a fixed bus schedule system to serve passengers in 110 routes. However, this type of bus assignment system created a problem in the company's operational and financial performances. The objective of this paper is to develop an optimum bus assignment method using Linear Programming (LP). After thorough analysis of the existing bus scheduling system, the LP model is developed and used to determine the optimal number of buses for each route in four shifts. The output of the LP-model is then validated with the performances of the existing systems. The findings of the study show that the new model reveals better performances on the operating costs, bus utilization and trips and distance covered compared with the existing scheduling system. The enterprise's bus utilization improved by the new system and cut costs on the one hand and improves the service quality to passengers on the other hand. The authors recommended the enterprise to adopt the new bus assignment system so that buses can be assigned based on the demand distribution of passengers for each route at a given shift.**

***Keywords*:** Vehicle Scheduling, Bus Utilization, Linear Programming, Model Validation, ACBSE.

I. Introduction

Anbessa city Bus Service Enterprise (ACBSE) is the only public enterprise that provides urban public transportation service in the city of Addis Ababa since 1943.

Addis Ababa lies at an altitude of over 2,300 meters above sea level and is located at 9˚1'48"N and 38˚44'24"E coordinates with a population size of more than 4.8 million and 3.8% annual growth rate with 8% urbanization [6].

Bus scheduling is one of the operations planning process in bus Transport Company that deals about the proper assignment of buses to serve the expected passenger demand. The planning process in public transportation consists of different recurrent and complex tasks which start at a strategic level. At the operational level, collecting or forecasting the number of passengers at each transfer point is most of the time fully unknown [5][35-39].

The decision-making process of bus assignment is however, a trade-off between service quality and operating cost for the bus operating companies. It is because; using too many buses incurs more operating cost to the company whereas too few buses decrease the service quality level. ACBSE currently serves 110 routes that connect different parts of the city using 690 operational buses. The number of passengers shows high variability during each periods of time that requires fluctuation of number of assigned buses in each route. But, the enterprise uses a fixed number of buses scheduled per route in its operation throughout the day. This resulted in, the fact that, some buses move empty while others are overcrowded, which subsequently result in poor performance on bus utilization, distance travelled, number of trips and service quality[3]. In this paper, the bus assignment and scheduling problems faced in ACBSE is modeled and analyzed using Linear Programing (LP) model. It is used to determine optimum bus assignment that can improve the existing bus schedule and assignment systems. Thus, this paper first focuses on developing a demand oriented LP-model for the bus assignment problems of ACBSE in four operating time periods in a day based on the 93 selected routes. For simplicity the four operating time periods named as shift for the purpose of this research.

The remainder of this article is organized in the following sections: section 2 covers the literature review; section 3 addresses the data collection and existing schedule techniques of the enterprise; section 4 discusses the LP model development processes; section 5 presents the performance comparison between the existing and the improved system; and section 6 gives the conclusion of the study.

II. Literature Review

The task of designing delivery or pickup routes to service customers in the transport and supply chain is known in the literature as a Vehicle Routing Problem (VRP) [15]. Dantzig and Ramser [10] proposed VRP for the first time under the title "Truck dispatching problem" with the objective of designing optimum routing of a fleet of gasoline delivery trucks between a bulk terminal and a large number of service stations. VRP is a generic name given to a whole class of problems in which a set of routes for a fleet of vehicles based at one or several depots must be determined for a number of geographically dispersed cities or customers [11, 12, 13, 27}. It is defined by a depot, a set of geographically dispersed customers with known demands, and a set of vehicles with fixed capacity [9, 12, 23]. In addition, customers must be visited exactly once and the total customer demand of a route must not exceed the vehicle capacity. In general, the objective of VRP is to minimize the overall distribution costs.

The general or classical VRP consists of designing a set of at most *K* delivery or collection routes such that: each route starts and ends at the depot, each customer is visited exactly once by exactly one vehicle, the total demand of each route does not exceed the vehicle capacity and the total routing cost is minimized.

Vehicle Scheduling Problem (VSP) is one of the branches of Vehicle Routing Problems (VRP) and its main function is to schedule vehicles to trips according to passenger demand and resource availability. The VRP can be represented in graph theory. Let G = (V, A) be a complete graph where, V = {0, 1 . . . n} is a vertex set and A is an arc set. Vertices j = (1 . . . n) correspond to the customers, each with a known non-negative demand, D_j, whereas vertex 0 corresponds to the depot. A non-negative cost, C_{ij}, is associated with each arc (i, j) ε A and represents the cost, distance or time of traveling from vertex i to vertex j [1, 26].

The most common objective of VSP is mainly to minimize the number of vehicles required and to reduce the daily operating cost [1, 4, 16, 17, 18, 22, 23, 28, 33]. There are different approaches and models used for vehicle scheduling problems. Among the many others, Xue, et al., [32] developed a model for Uncertain Optimization of Vehicle Scheduling in Open Coal Mine with the objective to use the minimum number of truck under the condition of fulfilling the task or to find the minimum expected number of trucks to be used. A mathematical model for the bus scheduling problem to determinate the bus departure rate as a function of time was also introduced by Salzborn [8].

The other transportation scheduling problems such as driver scheduling, bus controlling strategy and air craft scheduling are also approached by different authours with similar VRP concept [21, 29, 34]. For example, genetic algorithm techniques for driver-scheduling problem [2, 5], lagrangean relaxation of a linear integer-programming problem with a sub-gradient optimization and tree search procedure for crew scheduling problem [14, 21, 29], a stochastic-demand scheduling model for aircraft scheduling [34].

Mehmet, et al [30] present a model and related analysis for scheduling and routing of public buses in Kuwait. The linear programming model is developed to determine the optimal number of seats required for the selected routes at a given time slots. The model developed by Mehmet, et al., [30] aggregated the different bus capacity as seat rather than considering heterogeneous fleets. Moreover, after solving the model in hourly time slot, the bus assignment was made on shift basis.

The bus controlling strategy is thus a very important issue to improve the reliability of bus service and widely addressed by many authors [4, 7, 19, 20, 24, 25,]. Most of the VRPs are very complex, general and Non-Polynomial-Hard (NP-hard) by their nature, which could not be implemented easily. However, the model developed in this paper is new by its nature, introduce some new parametric value and can easily be with implemented with little modification by any public transport system.

III. Research Methodology

The methodology used in this research has followed the following basic four steps. These are data collection, model development, running the model and validating the model.

A. Data Collection

Though the enterprise is operating on 110 routes, the data collection focuses only on the first 93 routes, which have been used in the bus operations for more than a decade. The remaining routes are new and do not have historical data for the model analysis. The data collected includes route performances, number of passenger served, total trips made, revenue collected, operating cost and total distance covered. The data regarding the available facility of ACBSE; such as the number of buses both operational and non-operational and their capacity, bus travel time, route length and working hours were also collected from the current time table. The data were analyzed and organized per shift per route basis for validation purpose. In this paper shift means the working time period based on demand distribution.

Shift	Time Interval	Duration (Min.)	Demand Proportion (%)
Morning Peak	6:15-9:30	195	40%
First off-peak	9:30-15:30	360	20%
Evening peak	15:30-19:30	240	35%
Second off-peak	19:30-21:00	90	5%
Total		870	100

Table 1: Demand proportion and duration of each shift

As shown in Table1, ACBSE dispatched an average fleet of 534 buses and transported about 640,000 passengers per day in 110 routes. In addition to these, peak hour services are operated on 37 routes, and on average a city bus covers about 138km per day and makes 61.50 trips per day. The enterprise has two types of schedules for its operation in four shift, i.e. peak hour and off-peak hour schedules. These are two peaks and two off-peak shifts during its operation hours (from

6:30am to 21:0pm). The two peaks are: the morning peak from 6:30am-9:30am and after-noon peak from 15:30pm-19:30pm. The reaming hours are the off-peak in the morning and the after-noon shift. The time period, the time interval, the duration and the demand proportion of each time period or shift is shown in Table1.

B. Model Development

The current schedule of ACBSE shows the total distance coverage is about 78,964 kilometers and 5,504 trips per day for the 93 routes. Increasing kilometer covered means increasing service availability if the assignment of buses is based on the demand distribution of a given route, but incurs unnecessary cost if the assignment is not demand oriented. Due to this reason a very close look is required to design and analyze a model that can assign buses optimally and assess the bus utilization of the enterprise.

After analyzing the existing bus scheduling systems of ACBSE, an LP-Model was developed to obtain a solution for the bus assignment problems of the enterprise. The LP model developed in this study is easier either for computation or to apply for real problems of bus scheduling. It is a new approach in the literatures of VRP due to the fact that it addresses a mixed heterogeneous fleet in 93 routes and four shifts with many constraints. Moreover, unlike other variants of VRP, it introduces additional parameters like trip factor and demand proportion. It also directly used to find optimum numbers of trips made each bus type. The model is used to solve problem in public bust transport similar to Mehmet, et al [30] based on the demand distribution of passengers in 93 routes and four operating shifts. But unlike Mehmet, et al [30], it addresses the trips made by heterogeneous fleets directly in the model with more number of constraints in it.

C. Running the Model

Using the data collected, the LP model was fitted to its input parameters. The model developed was coded and solved using General Algebraic Modeling System (GAMS) optimization software[1]. The resulting solution of the LP-model was the number of trips per route per shift for each type of bus. After obtaining the solution, the number of trips was converted into number of buses per route per shift for each type of bus.

D. Model Validation

The LP model was analyzed to identify potential areas of improvement in the bus scheduling and assignment problem of ACBSE. It is also used to assign buses to a given route at a given shift based on the demand distribution of passengers in the four operating shifts in 93 routes. The findings of the LP-model were validated by comparing its performances with the performances of the existing bus scheduling systems of ACBSE. The validation was made on four performance measuring parameters namely bus utilization, total number of trips made, total distance travelled and various operating costs.

IV. LP-Model development

The LP-model deals with the assignment of optimum number of buses for each shift with the available fleet size of the company and different constraints in such a way that bus utilization is improved and operating costs are reduced with better service level. The model determines the total number of buses required with the objective of optimizing the number of buses required so that the operation cost would be minimized indirectly. ACBSE has four types of buses (DAF, Mercedes, Single and Articulated Bishoftu[2]) categorized in to two types based on their seat capacity.

The 30 seat capacity bus with total capacity of 60 passengers is labeled as *bus type-1* and the 45 seat capacity with total capacity of 90 passengers as *bus type-II*. Each of them has a fleet size of 600 and 90 respectively. The total bus capacity is computed as the sum of the seat and standing capacity. For this paper, it is determined based on international standards [31]. Thus, the objective function of the LP model is to determine the optimum number and mix of these two types of buses.

Let x_{ij} and y_{ij} is number of trips made by bus type-I and bus type-I, then the LP model that determines the optimum number of trips required per route per shift is formulated as:

$$Minimize \sum_{i=1}^{93} \sum_{j=1}^{4} (x_{ij} + y_{ij}) \tag{1}$$

Subject to

$$60x_{ij} + 90y_{ij} \geq D_{ij} \tag{2}$$

$$\sum_{i=1}^{93} \sum_{j=1}^{4} x_{ij} \leq 600 * \sum_{i=1}^{93} \sum_{j=1}^{4} T_{ij} \tag{3}$$

$$\sum_{i=1}^{93} \sum_{j=1}^{4} y_{ij} \leq 90 * \sum_{i=1}^{93} \sum_{j=1}^{4} T_{ij} \tag{4}$$

$$\sum_{i=1}^{93} \sum_{j=1}^{4} (x_{ij} + y_{ij}) \leq 93 * \sum_{j=1}^{4} w_j \tag{5}$$

$$x_{ij} \leq 600 * P_i \, T_{ij} \tag{6}$$

$$y_{ij} \leq 90 * P_i \, T_{ij} \tag{7}$$

$$\sum_{i=1}^{93} P_i = 1 \tag{8}$$

$$x_{ij}, _{ij} \geq 0 \tag{9}$$

$$\forall_i, i = 1,2,...93, \forall_j, = 1,2,3,4$$

Where: i = Route index, j = shift index, D_{ij} = Passenger demand of route i at shift j, P_i = trip proportion for route i, w_j = Minimum number of trips required at a given shift j, T_{ij} = Trip factor, maximum trips a bus can made on route i at a given shift j.

Equation 1 is the objective function that minimizes the total number of trips required per route per shift. Equation 2 ensures the total trips made by the two type of buses must

[1] The GAMS code was running within 0.15 seconds on 2.4G.Hz, Window7 Home Premium, 4GB RAM and core (i3) Toshiba Laptop computer.

[2] The single and articulated Bishoftu buses are locally assembled buses in Ethiopia

satisfy or exceeds the demand of route *i* during shift *j*. Equation 3 and 4 also ensure the total numbers of trips to be made is less than or equal to the total available trips made by bus type-I and bus type-II respectively. Equation 5 entails the number of made by either type of buses be at least equals to the minimum number of trips required for a given route *i* during that shift *j*. Equation 6 and 7 are the number of trips assigned to route *i* on shift *j* less or equals to the number of trips available for route *i* and shift *j* for bus type-I and type-II respectively. Equation 8 ensures the sum of all the trip proportion must be unity and finally Equation 9 indicates the non-negativity restriction. The model introduces a new approach by including different bus types in a simple LP model. It also assumes 30 minutes for one round trip for each route as a cycle time for all the shifts. This is used to determine the total number of trips required by each type of bus for route *i* during shift *j*. The actual number of buses to be used for the corresponding routes and shifts can be obtained from the total trips.

The travel time of bus on a given route is the total sum of passenger boarding and alighting time (dwell time), tea and lunch break, acceleration and deceleration at bus stops, traffic light and transfer time between each stop. However, few considerations were also taken into account both in terms of the functionality of the model itself and its output. In particular, the model was run once for all of the four shifts. Although there were different bus sizes considerations in ACBSE, constraint 2 includes bus size 60 and 90, which is are taken from the international urban bus standards. The number of buses will be checked to make sure w_j is met for all time slots. The results obtained may be fractional but rounded later into upper integer values.

From the model, some of the parameters need to be defined for clarity. Owing to this, the minimum number of trips required at shift *j* to meet the maximum allowable cycle time of 30 minutes. It depends on the duration of the time period and maximum allowable waiting time at a given shift.

The value of w_j which is the minimum number of trips required at shift j to meet the maximum allowable waiting time depends on the duration of the time period and maximum allowable waiting time. For example, if a single trip time for a given shift is 30minutes and the length of the time period is 4hours for a given shift, then a minimum of 8 trips are required to limit the maximum waiting time of passenger to 30minutes. This means, there should be at least one bus in every 30minutes or half an hour for each shift for the quality of the service. w_j is computed as follow:

$$w_j = \frac{\textbf{\textit{Total Duration for Shift j (Minutes)}}}{\textbf{\textit{30 Minutes}}} \tag{10}$$

Thus, using equation 10 and the information given in *Table1*, the value of w_j for the four shifts are computed and reported in Table2.

The other parameter that needs to be determined is the trip factor, T_{ij}. This is the number of trips a bus can make on route *i* at a given shift ***j***. Since the model computes the total trips that are required per route per shift, the trip factor is used to compute the available number of trips per route per shift. It is given by:

$$T_{ij} = \frac{\textbf{\textit{Total Duration for Shift j (Minutes)}}}{\textbf{\textit{Single trip travel time for route i}}} \tag{11}$$

P_i is trip proportion of a given route *i* from the overall routes. This factor is used to allocate trips to route *i* from total available trips. Numbers of trips for each route are also computed based on the proportion of the total trips of all the routes.

$$P_i = \frac{\textbf{\textit{Daily Demand of Route i}}}{\textbf{\textit{Total Daily Demand of all Routes}}} \tag{12}$$

D_{ij} is average daily passenger demand of route i during shift j. It is obtained from the secondary data by multiplying the average daily demand of route *i* by the demand proportion of shift *j* shown in *Table 1*.

A. Input Parameters

To solve the LP-model, the input parameters, which are involved in the model, are need to be determined. These parameters are either computed or obtained from the secondary data. The sample input parametric values of some routes are reported in Table2.

Route No.	Demand	Pi	Demand (D_{ij}) per Shift				Trip factor (T_{ij}) per S			
			D_1 (w_1=7)	D_2 (w_2 = 12)	D_3 (w_3 = 8)	D_4 (w_4 =3)	T_1	T_2	T_3	T_4
1	4126	0.014	1650	825	1444	206	7	12	8	3
2	3497	0.012	1399	699	1224	175	4	7	5	2
3	11030	0.038	4412	2206	3860	551	4	7	5	2
4	3029	0.010	1212	606	1060	151	3	5	3	1
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.
92	3836	0.013	1534	767	1342	192	4	8	5	2
93	2029	0.007	812	406	710	101	5	9	6	2

Table 2: Input parameters for the LP Model for some routes

First and foremost, the input parameters namely, P_i, T_{ij}, D_{ij} *and* w_j that are used to solve the model are determined. The parameters namely P_i, T_{ij}, *and* w_j, are computed or derived and parameter D_{ij} *is* obtained from the secondary data. The sample input parametric values of some routes are reported in *Table2*.

B. Model Output

The LP model developed is solved based on the average daily demand for the last 19 months in four operating shift time. The daily passengers' demand for the last 19 months was collected and then the average daily passenger' demand of each month was computed per route per shift based on the trip proportion (P_i) of route i, as reported in Table2.

The output of the model shows the total number of trips required to serve the average demand of each route on a given shift of the two types of buses. The sample output of the LP model is shown in *Table 3*.

The output is reported by taking the upper integer value. As shown in *Table3*, for example, for route 3, 61 trips by bus type-I and 14 trips by bus type-II were required for shift one.

There are also cases in which no trips are required by bus type-I in the off-peak shifts. Since the LP model produces number of trips required, the output has to be transformed into number of buses required for each route in a given shift.

Route No.	Shift 1		Shift 2		Shift 3		Shift 4	
	BT-I	BT-II	BT-I	BT-II	BT-I	BT-II	BT-I	BT-II
1	19	9	0	10	14	11	0	3
2	19	5	5	8	15	6	0	2
3	61	14	14	24	48	17	0	7
4	18	3	6	5	15	3	2	1
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
92	21	5	0	9	17	6	0	3
93	11	4	0	5	9	4	0	2
Total	1541	402	174	618	1231	490	18	156

Table 3: Number of trips per shift per route for some routes (BT=Bus type)

C. Assigning buses to routes

From the output of LP-model there are about 4,630 total trips required to serve the average daily demand. The actual number of buses required for a given route *i* during a given shift *j* depends on the trip factor. That is the number of trips that can be made by each bus type during a given shift. Thus, the output needs to be transformed to number of buses required for each route per shift based on the possible trips that a bus can make during a given shift *j* on each route *i*. From the output of the LP model shown in *Table 3,* the number of trips can be transformed into number buses using the following equation.

$$\boldsymbol{Number\ of\ Bus} = \frac{\boldsymbol{Number\ of\ Trips}}{\boldsymbol{T_{ij}}} \qquad (13)$$

Sometimes the output of the LP-Model is small for some routes. But after adjusting them, the number of buses required for such routes is changed into two buses. This would ensure to have at least two buses per route per shift in a given cycle time that is 30 minutes. It helps to allocate the two buses on both ends of the route; that is one on the going trip and the other on the returning trip. This is because the demand during a given shift *j* on route *i* is distributed and available on both direction of the route. Sample of number of buses per route per shift is reported in *Table 4*.

The actual number of buses required for each shift varies depending on the demand distribution. Due to this reason, the number of buses required during peak periods is higher than that of off-peak periods. Thus, some of the buses that operate during morning peak period have to wait on the bus stops until they are required for the evening peak.

V. Model Validations

The output of the model is then evaluated using various performance measuring parameters. For the validation purpose, different comparisons were mad between the existing and the LP improved systems. The comparisons made were based on bus utilizations, distance and trips covered and the different operating costs of the enterprise and each of them are discussed in the following sections.

A. Bus utilization

After assigning buses to each route and each shift, then the improvement achieved by the LP model were compared with the existing bus utilization of ACBSE. Bus utilization is computed as the ratio of the number of passengers getting on the bus to the passengers carrying capacity. The average daily bus utilization of the existing and the improved systems are shown in *Figure1*. The findings show that the improved system has better bus utilization than the existing one. The existing system has a maximum of about 125% daily bus utilization, which is very congested, while the improved system has a maximum utilization of 97%.

	Shift 1	**Shift 2**	**Shift 3**	**Shift 4**

Route No.	BT-I	BT-II	BT-I	BT-II	BT-I	BT-II	BT-I	BT-II
1	3	1	1	1	2	1	1	1
2	5	1	1	1	3	1	1	1
3	16	3	2	3	10	4	0	3
4	6	1	2	1	4	1	2	0
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
92	5	1	1	1	3	1	1	1
93	2	1	1	1	1	1	2	0
Total	**396**	**94**	**114**	**88**	**269**	**94.8**	**121**	**79**

Table 4: Number of buses per shift per route for some routes

This shows how the passenger congestion and the service quality are improved in the new system. The average bus utilization for the improved systems is about 66.33% and for that of the existing systems is 64.26%. Though the average utilization of both of the system seem close to each other, in the improved system most of the utilization lies between 60% and 80% whereas in the existing system had unbalanced utilization which is sometimes felled below 20% and other times above 120%. This leads the researchers to make further comparisons on the bus utilization based on shifts.

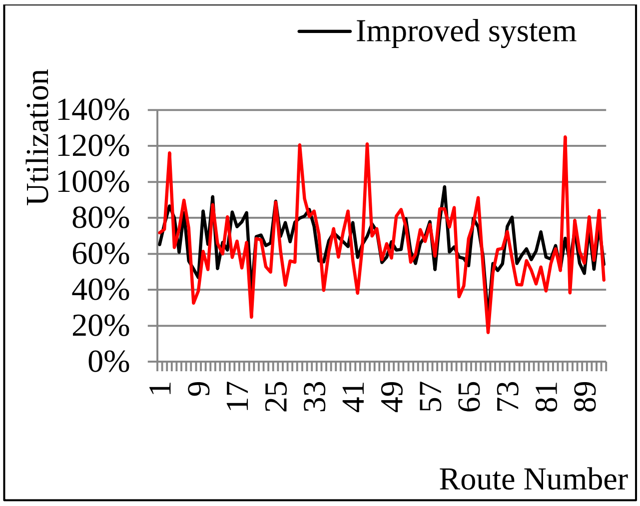

Figure1: Average daily bus utilization

As shown in *Figure 2*, a close analysis of bus utilization based on shift, the new system exhibited a significant improvement. The improved system shows a bus utilization of 89.8% during morning peak, 51.19% during first off-peak, 82.24% during evening peak and 42.1% during second off-peak periods. The improvement over existing systems, in this case, is 19.75% during first off-peak and 12.15% during the second off-peak. The bus utilization of the improved system also reduces the passengers' congestions in peak hours, i.e. bus utilization decreases from 116.1% to 89.8%. Thus, the improved system has stable and consistent bus utilization with better service quality. It also indirectly increases the service quality by reducing over congestion during peak periods and reduces the operating cost during off-peak periods.

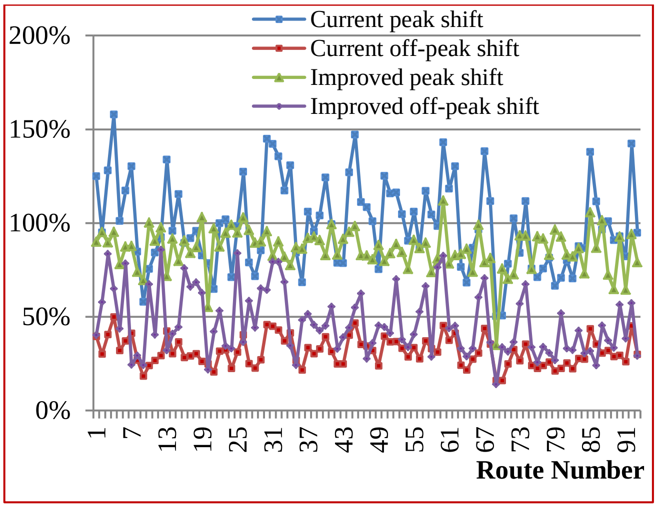

Figure 2: Average bus utilization for peak and off-peak shifts, Current Vs Improved system

B. Distance and trip coverage

Total Kilometers covered by buses for route *i* is the sum of Kilometer covered during all the four shifts. *Figure 3* shows the total distance coverage of the current and the improved systems. The distance covered on each shift was computed by multiplying the number of buses assigned to a given route at that shift by the number of trips that can be made by a single bus and by the route length. The total distance covered by the improved system is 70,964 Km per day; while for the existing system is about 78,963.7 Km per day. This shows a reduction of 10.13% in the daily distance coverage to serve the same number of passengers.

The total daily trips made for the improved system is also computed for each shift by multiplying the number of buses assigned and the number of trips a single bus can make during that shift. The total trips covered for the existing systems were 5,504 trips per day while 4,630 for improved systems. This also shows an improvement of 874 trips per day over the existing system. The improved number of trips achieved was 15.88% with a 10.13% reduction on the daily distance travelled. This improves also will have a subsequent effect on the maintenance cost, spare part consumption, fuel consumption and depreciation of buses.

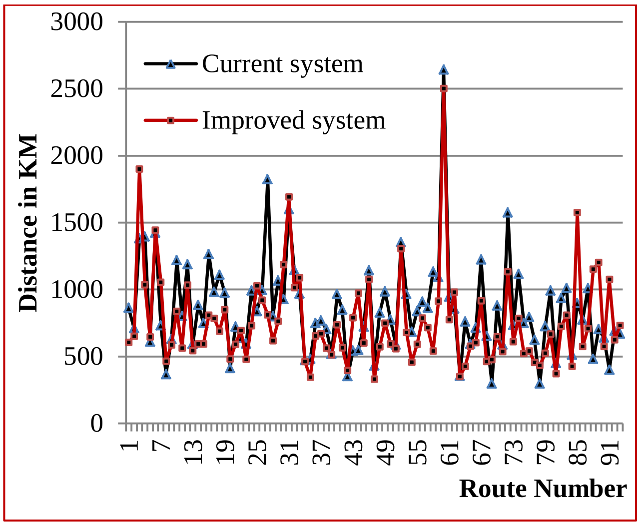

Figure 3: Distance coverage; Current Vs Improved system

C. Operating Costs

The improvements made were also validated using the various operating costs of the enterprise. Total daily operating cost for each route is the sum of operating costs for all the shifts. From the comparison made, the findings show that the average daily operating cost for the existing system is 1,101,283.68 ETB (ETB = Ethiopian Birr and 1USD = 18.90ETB as of March 4, 2013) while for the improved system is 949,991.49 ETB. This shows a saving of 13.74% per day over the current system. As shown in *Figure 4*, the improvements made by the new system are achieved nearly in all the operating costs of the enterprise. As compared to other operating costs, larger saving is observed on gas oil. This may be due to the improvement achieved on the total distance travelled.

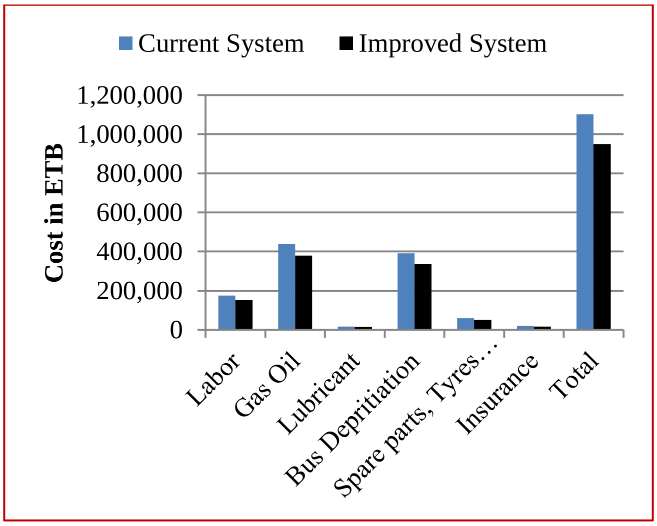

Figure 4: Current Vs Improved operating cost

VI. Conclusions

The findings of the study show that the existing scheduling systems of ACBSE has shown low performances on the bus utilization, operating costs, daily trips and distance covered. This is mainly due to the fact that fixed numbers of buses are assigned to routes without considering the variability of demand. However, the operational performances of the LP-model have shown better performance improvement over the existing bus scheduling system, almost, in all of the above parameters.

The existing bus scheduling system has lower average utilization of buses compared with the improved one by 2.1%. The bus utilization per route per shift also shows significant improvement over the existing system when the comparison was made based on shift. With regard to cost, the improved system results in a saving of 13.74% (151,292.19 ETB) in the operating costs of the enterprise. Moreover, it also results in a 10.13% saving on the total Km covered with 80 additional available trips per day. In addition to the saving in all the parameters, the improved system also reduces the waiting time, improves the service quality and reduces passenger congestion by scheduling buses based on the international standard bus capacity. It also secures a minimum of one round trip in every 30 minutes for each route to improve the service quality. The new system has also a significant reduction on the total Kilometers covered while improving the total trips made on daily basis. The LP-Model focuses only improvements without affecting the existing routes used by the enterprise and some of the improvements achieved are not significant. But designing new routes may also bring radical improvement the performances of the enterprise. Therefore, further study can fill the gap related designing new routes, passengers' satisfaction and level of service quality improvement.

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