Fleet Service Scheduling for Transit Movement on an Urban Arterial in Ilorin, Nigeria

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Abstract

Public transit schemes operating in unplanned urban centres are characterized by traffic induced congestions with consequent unfriendly, uneconomic and unreliable experiences of the commuters who are mostly captive. This study was carried out on the University of Ilorin transit scheme in order to establish the desired improvement strategies for effective movement of captive commuters on the route who are mostly students. A passenger demand estimate was made alongside the commuters' transit operational characteristics determination with both observatory and questionnaire approaches. The study showed that there is no schedule movement of vehicles known to the commuters. The load factor of the buses in the fleet is presently 2.2 which is considered crowded. The analysis showed that two and three buses should be added to the morning and afternoon fleets respectively, each of which presently runs three 55-seater buses as immediate necessary measure to improve commuting. Cycle lengths of 65 minutes and 78 minutes are designed for the morning and afternoon operations respectively. A schedule for movement of the buses is designed which should be made available to the commuters to enhance their trip planning. The travel demand forecast shows that by 2027/2028 alternative bigger transit vehicles such as light rails should be introduced along the movement corridor to meet travel demands. Bus Rapid Transit along dedicated lanes can also be considered which will reduce travel time.

Keywords: Transit, Fleet Size, Schedule, Headway, Load Factor.

Introduction

Over half of all people in the world currently live in cities, and it is projected that the population will grow to two thirds of the global population by 2050 (BRT Planning Guide, 2017). The development and availability of an efficient, effective and reliable public transportation therefore remains crucial in the developing cities and urban centres. In view of insufficient availability of means of mobility in case of number of passenger carriers, a lot of individuals use their private vehicles for commuting as complement to the inefficient public transit schemes. This practice brings about a disorganized public transportation scheme in a number of cities and urban centres (Lehman Center for Transportation Research, 2015). Reason for inefficient transit systems as identified by (BRT Planning Guide, 2017) include lack of service planning process which needs to be developed and seen as essential for efficient transit. Auto commuting contributes to urban traffic congestion, urban parking problems, increased pollution, sprawling development and accident fatalities among others. Ilorin metropolis, Nigeria where the University of Ilorin is situated shares in the challenging situation of inefficient public transportation along its student movement corridor. In order to ameliorate the challenges faced by commuters on the movement corridor, the University Transport Management updated its fleet with three high occupancy vehicles (HOV) to improve its Bus Mass Transit Scheme. It also upgraded and liberalised its bus park facilities to allow private commercial vehicle operators free access to the facilities among other measures. However, despite the measures taken, the challenges of delay, long queues and long loading periods and unpredictable commuter waiting period due to uncertain bus arrival/departure time patterns subsist. This is a persistent concern for commuters that patronize the University Bus Mass Transit Scheme. These challenges are similarly, commonly experienced on many movement corridors in Nigerian cities and urban centres including University campuses where students are captive commuters because majority of the institutions do not have sufficient residential accommodation for the students. Students live off-campus and commute to school daily for lectures and other educational instructions. It is in view of the need to address the problem that a study was commenced. In the on-going study, Automatic Vehicle Location Equipment (AVLE) technologies were installed into buses in the University fleet in a bid to enhancing the transit operations along the movement corridor using the ITS technology.

Service planning is the process of planning and designing public transit service to meet a public transit agency's goals and objectives. Activities commonly associated with service planning: include i. Network design ii. Route design and stop layout iii. Frequency determination iv. Time tabling and Vehicle scheduling and v. Crew scheduling (Lehman Center for Transportation Research, 2015). Service planning process is aimed at maximizing the quality of service to users while minimizing the costs. Trade-offs thus need to be made and various optimization techniques come into the process. Service planning is a dynamic process that involves constant re-examination of the details of its physical, technical and operational characteristics. This study examines the current operations of the public bus transit on the University of Ilorin movement corridor with particular reference to the beneficiaries' assessment with the aim to improve the effectiveness of its services with respect to the service planning building blocks. The objectives are to: i. determine commuters' assessment of the services rendered by the transit service, ii. determine the needed frequency of service and the optimum fleet size to meet commuters demand and iii. develop an anticipated trip schedule for vehicles in the fleet.

Studied transit corridor

University of Ilorin is a tertiary educational institution located in Ilorin, Kwara State, Nigeria. It covers a land mass of 75000 hectares. The University has a work force of 2,870 personnel and a student population of 56,718 (Annual Report, 2018). In addition to its fundamental function of providing tertiary education, the institution also has a primary and secondary school and other autonomous ventures. The University Transport Management manages two bus terminals; one within the school (the School Park) and the other off-campus in Tanke (Tanke Terminus) in Ilorin about 8.769 km away and within the township growing development. The only commercial transportation mode allowed within the University premises is the tricycle which is privately owned and operated. The transportation services enjoyed by commuters coming into and moving out of the University campus are midi-buses (9 passenger-seater), taxis and mini-buses(13 passenger-seater) all privately owned while the University operates 55 passenger-seater HOV. The Kwara State Government also operates a fleet of 55-seater HOV along the movement corridor though their operations and management are in no way coordinated with the University HOV. The major bus stops of these vehicles are; Oke-odo, Tanke Terminus, Tipper garage, Challenge, Post Office, Taiwo Road and General Hospital. Points of maximum loading points for the various types of vehicles include Tanke Terminus, Challenge and Post Office at Morning peak and the School Park at Afternoon peak. The terminals of School Park and Tanke Terminus are designed to handle the different vehicle types with each mode provided a dedicated section in each of the terminals as loading point.

The University of Ilorin Bus Mass Transit Scheme is a collaborative intervention between the University authority and the Student Union of the institution. Aside the daily intra city shuttle between the University School Park and Tanke Terminus, the University mass transit buses are also used for other activities like educational tours, students' sport trips and hire services to the public which take the buses outside Ilorin township. This is a sort of disruption to the expected regulated supply of transit means to the commuters during the withdrawal to meet these other purposes. The bus scheme is managed by the Mechanical Section of the Works department in the most economical manner. The scheme has three HOVs used as mass transit buses and each seats 55 persons. The scheme is Student-based and it operates two sessions daily. Morning session starts at 7am and lasts till 10.30 am while afternoon session starts at 2pm and lasts till 8.20 pm. However, the actual operational duration for each session depends on demand. Fare of ₦20 per trip is collected at the point of entry into the bus upon identification as student.

Material and Methods

Service planning model for university transit scheme

The activities involved under service planning process are in network, route design and frequency determination which tend to be driven in part by political and economic considerations, and the activities of timetabling and vehicle and crew scheduling that are considered more technical and tactical decision driven process. This includes the transit agency reviewing or changing schedules sometimes appropriately assisted by software tools (depending on the densification or complexity of the transit route network)that can generate high quality solutions in a short period of time(Lehman Center for Transportation Research, 2015).

Frequency determination

Service frequency (number of directional bus trips within a specified period of time)is usually dependent on the headway (the amount of time between consecutive directional trips).The headways in various forms are used to determine frequency of service on a route which are generally influenced by the demand for service (passenger load) and the capacity of the vehicle. The most desired types of headways are (Wiki Loves Africa, 2019): *Policy headway* is the specific headway that meets policy goals as set by transit board (regardless of demand).It usually relates to providing a minimum level of service along a route when demand on the route is low (e.g. on lightly travelled route or at off peak times). This could include 30-minute or 60-minute headways, for example; *Capacity headway* is the headway determined based on capacity limitations, it is such that the vehicles are just filled at the maximum load point on the route. The *Load management headway* is the headway where policy headway or capacity headway do not apply, the 'capacity' of a vehicle becomes at best a rough approximation where passengers are allowed to stand. Thus, the headways become based on some arbitrary value of the average load factor (i.e. the ratio of passengers to seats) at the maximum load point that is intended to represent the limit of acceptable crowding. In such a situation of overload, the typical way of determining frequencies is based on managing load at the peak load point along the route. Equations 1 and 2 are valuable for the frequency and headway respectively.

$$f \geq \frac{P}{CX} \quad [1]$$

where f = the frequency, that is the hourly passenger demand/hourly offered capacity of vehicle(s) in the fleet,

P = maximum hourly load at peak load point (passenger/h)
X = load factor (max allowable vol-capacity ratio) and
C = vehicle capacity

$$h = \frac{60}{f} \quad [2]$$

where h= headway (minutes)
f = frequency (veh/h)

Fleet size determination

One of the key purposes of developing a public bus service plan is to know how many vehicles will be required to service the movement corridor effectively. Parameters required to determine the fleet size are the Cycle time (T), the frequency (f) and the headway (h).

The collected data was analysed to determine the travel time needed for vehicles to run from one end of the route to the other and return. The Cycle time (T) was determined as the result of the sum of the travel time, the layover time and recovery time as shown in Equation 3.

$$T = T_o' + T_o'' + tt' + tt'' + t \qquad [3]$$

where T = cycle time

T_o'= operating travel time between departure from a terminal and its arrival at the other terminal on line,

T_o'' = is the return trip travel time,

tt' and tt'' are layover times at each of the terminals, and t is the recovery time needed to dampen variation in schedule (sometimes expressed as a % of T_o', T_o'').

The fleet size is given as:

$$N = \text{nhint}\ (T/h) \qquad [4]$$

where N = no of buses needed to service the route

T = cycle time

h = headway

nhint = next higher integer

Scheduling

Route schedule or timetable, gives the times that successive buses pass points called time points. Route schedule is most commonly constructed by maintaining approximately uniform headways among successive vehicles during period of time known as schedule blocks. Schedule blocks commonly include base (off peak), morning and evening peaks and sometimes weekends and holidays schedules (Banks, 2002).Traditionally, transit agencies prepare service schedules which are published for public usage in printed form. Nowadays, public timetables are also available in a variety of electronic formats.

Assessment of existing system and facilities

Observatory study and interview

An observatory study was carried out on the present operations of the HOV buses in the University transit scheme fleet. Interviews were also conducted on the operators and management of the transit services to elicit information on the present deployment of resources for operations by the management of the University of Ilorin Mass Transit Bus.

Commuters' assessment

Services are designed to maximize customers' satisfaction and needs. Questionnaire was administered on commuters to obtain their perception on the level of service of the bus transit (EN 13816, 2002). The population count of the commuters per day was carried out for a week by counting the number of commuters boarding each bus per trip. The obtained highest count per day in the week was used in Equation 5 (Yamane, 1967) to compute the required number of questionnaires/sample size (n) to be administered in order to facilitate an accurate conclusion (Singh and Masusku, 2014). Confidence level of 95% was applied.

$$n = \frac{N}{1 + Ne^2} \quad [5]$$

where n = sample size
N = population count (in this case number of commuters per day)
e = permissible error = 5%

The commuter assessment survey was preceded by a pilot survey to test the suitability of the designed questionnaire in order to address any ambiguity respondents can be faced with in the course of responding to the questions. The sample size of the pilot survey was taken as ten percentage of the sample size to be administered.

Operational study

Operational study was conducted on the scheme to determine the bus route operating characteristics. The bus route was divided into three segments; Bus Park to Gate, Gate to Oke-odo and Oke-odo to Tanke terminus. The arrival and departure times and the time taken for the buses to travel each segment was recorded during each operational period. The peak hourly demand was also obtained at the maximum loading points of Tanke Terminus and School Park. The data was used to calculate the number of buses required. The estimated travel times between timepoints were determined from obtained travel times between the three aforementioned segment points.

Results and Discussion

Commuters' assessment

Table 1 shows the commuters count made for the five working days in a week. A sample size $(n)$of 360persons of the highest number of daily commuters of 2894 in the week was computed in Equation 4, hence, 360 questionnaires were administered.

Table 1: Daily Commuters Population Count (05/03/2018 – 09/03/2018)

Days	Session Population		Daily population
	Morning	Afternoon	
Monday	1199	1695	2894
Tuesday	896	1311	2207
Wednesday	788	1056	1844
Thursday	1019	1212	2231
Friday	632	957	1649

The obtained riders' assessment of the existing service is as depicted in Figure1.

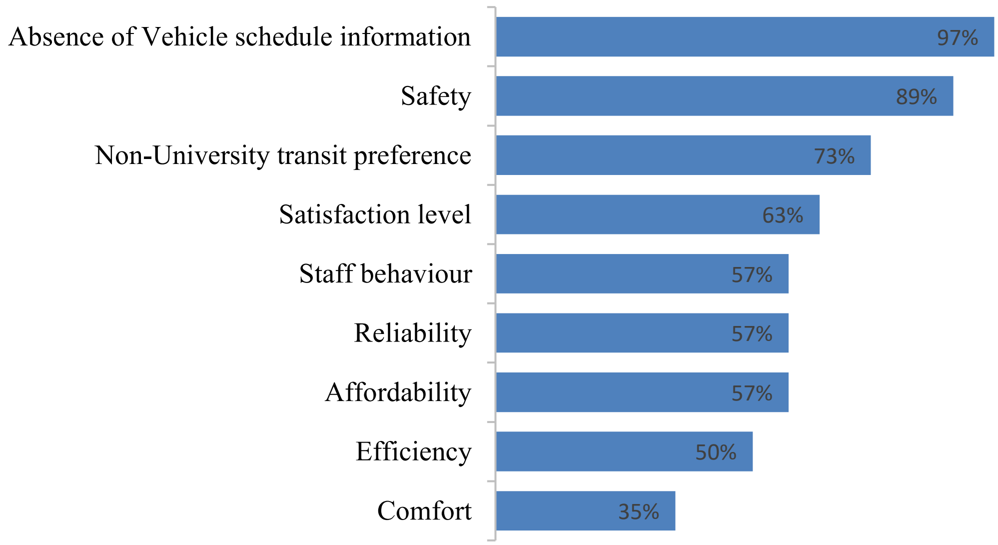

Figure 1: Commuters' Assessment

Operational survey

Span of service

The study showed that on a typical day, two block times of morning peak and afternoon peak are operated with three buses tagged Unilorin 21FG, Unilorin 22FG and 2Small maco in this study. Each bus has a seating capacity of 55. The seating arrangement in the buses was such that three passengers sat in each row and standing passengers fill the aisle which many passengers deemed as necessary though not convenient. The operating hours was 7:00 am – 10:30 am for morning operation and 2:00 pm – 8:20 pm for afternoon operation. The buses are operated only on weekdays of Monday – Friday.

Transit route and stops layout

The route map of the movement corridor is as shown in Figure 2. It runs from the University School Park to Tanke Terminus. Although service planning involves developing route and network of routes for transit systems, the dualised primary arterial on which the transit currently operates remains ideal for the scheme as it is the only road that presently leads directly to the University School Park from Tanke Terminus. The road is 8.769 km long. Bus stop spacing has a significant influence on the performance of a transit system. The bus stops layout as presently used by the transit is considered sufficient considering their locations and spacing as recommended by Adeleke & Jimoh (2012). The stops which are the timepoints are Tanke Terminus, Oke-Odo, Gate and School Park for Inward-bound trips while School Park, Gate, Oke-Odo, MFM, Sanrab, NNPC and Tanke Terminus are for the Outward-bound trip. The geographic locations of the Terminals and timepoints are given in Table 2.

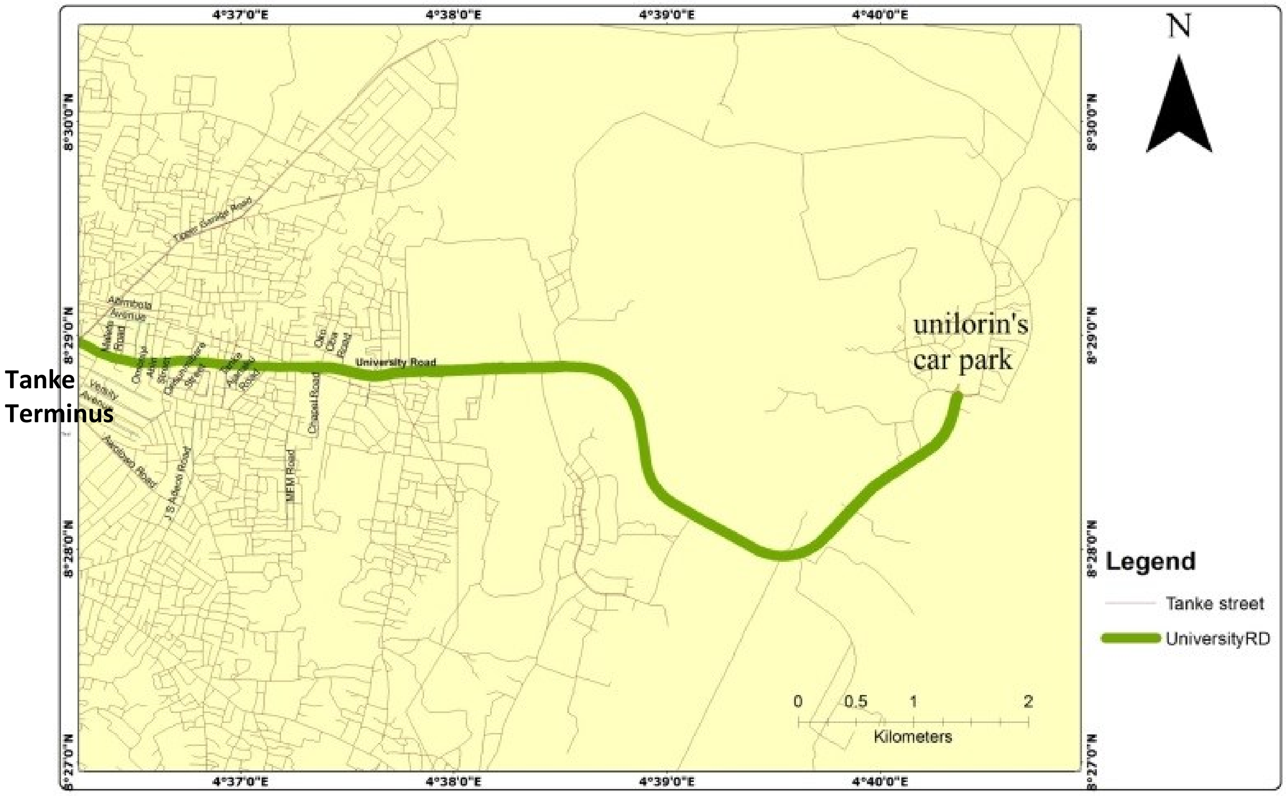

Figure 2: University of Ilorin Mass Transit Scheme Route Location and Stops Layout

Table 2: Terminals and timepoints chainages and coordinates

S/N	Bus Stop Name	Chainage (m)	Coordinates	
			Latitude	**Longitude**
1	School Park	0	8°28'8.68''N	4°40'21.00''E
2	Gate	5019	8°28'51.02''N	4°38'27.21''E
3	Oke-Odo	6386	8°28'48.72''N	4°37'40.20''E
4	MFM	7193	8°28'50.91''N	4°37'16.27''E
5	Sanrab	7714	8°28'51.76''N	4°36'5697''E
6	NNPC	8375	8°28'52.30''N	4°36'35.60''E
7	Tanke Terminus	8769	8°28'53.77''N	4°36'24.60''E

Source: Adeleke and Jimoh, (2012)

Bus operations

Morning peak operations

Table 3 shows a typical morning operation vehicles' movement profile. The study showed that on a typical day, morning operation began at 7am and ended at 10:30 am after ten combined trips from the three buses. Table 4shows the ridership data at Tanke Terminus which is the peak load point in the am from which the peak point hourly demand is obtained. It also gives the bus arrival, departure and loading times.

Table 3: A Typical Bus Movement Time Table during Morning Operation

Bus No.	Trip No.	Ter-minus	Oke-odo	Gate	Sch park	Sch park	Gate	Oke-odo	Ter-minus	T_o’ (min)	T_o’’ (min)	tt’ (min)	tt’’ (min)
22FG	1	7:12	7:15	7:18	7:28	7:32	7:41	7:44	7:57	16	25	15	4
2(small maco)		7:28	7:33	7:35	7:46	7:50	7:58	8:00	8:12	18	22	13	4
21FG		7:43	7:50	7:53	8:04	8:07	8:15	8:17	8:29	21	22	9	3
22FG	2	8:13	8:18	8:21	8:31	8:37	8:42	8:44	8:53	18	16	10	6
2(small maco)		8:26	8:31	8:34	8:45	8:48	8:56	8:58	9:03	19	15	13	3
21FG		8:39	8:47	8:51	9:01	9:05	9:14	9:17	9:26	22	21	15	4
22FG	3	9:04	9:12	9:16	9:31	9:35	9:43	9:46	9:59	27	22	12	4
2(small maco)		9:17	9:25	9:27	9:39	*	*	*	*	22	N/A	N/A	N/A
21FG		9:43	9:51	9:54	10:05	*	*	*	*	22	N/A	N/A	N/A
22FG	4	10:13	10:16	10:18	10:27	*	*	*	*	18	N/A	N/A	N/A

T_o’, T_o’, tt’ and tt” are running times and layover times
N/A – not applicable
*trip made in only one direction to School Park then to the garage awaiting afternoon operation

The highest number of passengers on a trip was 132 while the least was 97. The highest one-hour accumulated demand was 467 passengers between 7:43 am and 8:42 am and the lowest was 360 passengers from 7:12 am – 8:11 am. The lowest loading period was 9 minutes while the highest was 15 minutes in which 126 and 130 passengers were loaded respectively. The column on the accumulated demand over each one-hour period has some cells with N/A where a full hour of operation has not passed. The Cycle length (T) is obtained as the time interval between the departure time of a bus from the Tanke Terminus and its next circuit departure time from the same terminus. These were similarly determined for the afternoon operation as shown in Table 5.

Table 4: Transit Scheme Typical Morning Peak Period Operation Details and Hourly Demand

Bus No.	Bus Arrival Time (AM)	Bus Departure Time (AM)	Loading Period		Loading Duration (min)	No of Passengers	One-Hour Time Increment	One- Hour Accumulated Demand
			Start	End				
22FG	*	7:12	7:00	7:12	12	124	N/A	N/A
2(small maco)	*	7:28	7:13	7:28	15	117	N/A	N/A
21FG	*	7:43	7:29	7:43	14	126	7:12 – 8:11	367
22FG	7:57	8:13	7:58	8:13	15	118	N/A	N/A
2(small maco)	8:12	8:26	8:13	8:26	13	97	7:28 – 8:27	451
21FG	8:29	8:39	8:30	8:39	9	126	7:43 – 8:42	467
22FG	8:53	9:04	8:54	9:04	10	124	8:13 – 9:12	465
2(small maco)	9:03	9:17	9:04	9:17	13	112	8:26 – 9:25	459
21FG	9:26	9:43	9:28	9:43	15	130	9:04 - 10:03	366
22FG	9:59	10:13	10:01	10:13	12	132	9:17 – 10:13	374

* Buses are already parked at the Tanke Terminus before 7:00 am to commence morning operation
N/A – Not applicable

Afternoon operation

After morning operation, buses are moved to the garage at Works Department and returned to the School Park shortly before 2:00 pm for afternoon operation. The afternoon operation started with loading activities at 2:00 pm and ended at 8:15 pm. The observed typical movement profile by the buses during afternoon operation is shown in Tables 5 and 6. The first bus departed School Park at 2:20 pm while the last bus departed at 7:16 pm. The longest loading period was 20 minutes while the shortest was 10 minutes. The highest number of riders on a trip was 130 while the lowest was 107.

The load management headway approach as defined in Section 2.1.1is used in the study to determine the frequency of buses that will meet commuters demand. The services are designed around the peak hour and the peak load point (BRT Planning Guide, 2017; Lehman Center for Transportation Research, 2015). In the study, the terminals are the peak load points on the route. Tanke Terminus in the case of morning operation and School Park Terminus for afternoon operation.

In Tables 4 and 6, the average no of persons per bus are 120.6 and 121.1 riders/bus for morning and afternoon sessions respectively; therefore, Load factor (X) of 120.6/55 = 2.2 and 121.1/55 = 2.2 is obtained for both sessions.

A design load factor (X) value of 2.0 is used for the calculation of frequency (f) for the two blocks instead of the computed (X) value of 2.2for morning and afternoon peak periods as this will be a little more convenient for commuters in the bus to reduce the overcrowding of the buses.

Morning operation

The highest passenger per hour loaded at Tanke Terminus was 467.Thus, for morning operation, from Equation 1, f is given as $f \geq 467/(55x2) \geq 4.3$ buses/hr.

The headway is obtained using Equation2 as h = 60/4.3 = 13.95min; a 13 minute-headway is therefore used in planning.

The operational data in Table 3 gave an average travel time of 42 min; tt' = 13 min and tt' = 4 min thus the average Cycle time (T) for morning operations is 59 minutes; a 65- minute cycle time is therefore used for the design which gives 6 minutes for damping of variation in schedule.

From Equation 4 the Fleet size is obtained as:

N = nhint (65/13) = 5 buses needed for morning operation

Table 5: A Typical Bus Movement Time Table During Afternoon Operation

Bus No.	Trip	School park	Gate	Oke-odo	Terminus	Terminus	Oke-odo	Gate	School park	T_o' (min)	T_o'' (min)	tt' (min)	tt'' (min)
21FG		2:20	2:32	2:38	2:48	2:52	3:02	3:06	3:17	25	28	4	12
2(small maco)	1	2:38	2:49	2:51	3:04	3:08	3:19	3:22	3:32	24	27	4	12
22FG		2:48	2:58	3:02	3:14	3:19	3:26	3:31	3:41	22	26	5	10
21FG		3:30	3:39	3:42	3:53	3:56	4:06	4:09	4:20	24	23	3	13
2(small maco)	2	3:45	3:55	3:58	4:10	4:14	4:23	4:27	4:37	23	24	4	11
22FG		3:52	4:03	4:06	4:13	4:17	4:27	4:31	4:43	26	21	4	17
21FG		4:34	4:43	4:46	4:55	4:57	5:06	5:09	5:20	23	21	2	14
2(small maco)	3	4:49	5:00	5:04	5:15	5:17	5:26	5:30	5:41	24	26	2	17
22FG		5:07	5:17	5:23	5:38	5:44	5:53	5:58	6:18	24	31	6	13
21FG		5:35	5:42	5:45	6:00	6:03	6:11	6:20	6:30	27	25	3	15
2(small maco)	4	5:59	6:07	6:10	6:22	6:27	6:40	6:45	6:54	27	23	5	20

Bus No.	Trip	School park	Gate	Oke-odo	Terminus	Terminus	Oke-odo	Gate	School park	T_o' (min)	T_o'' (min)	tt' (min)	tt'' (min)
22FG		6:32	6:47	6:53	7:04	7:07	7:23	7:26	7:42	35	32	3	N/A
21FG		6:46	7:00	7:09	7:21	7:24	7:36	7:39	7:50	26	35	3	N/A
2(small maco)	5	7:16	7:30	7:35	7:46	7:48	7:57	8:00	8:11	23	30	2	N/A

T_o', T_o', tt' and tt" are running times and layover times
N/A – not applicable

Table 6: Transit Scheme Typical Afternoon Peak Period Operation Details and Hourly Demand

Bus No	Bus Arrival Time (PM)	Bus Departure Time (PM)	Loading Period		Loading Duration (min)	No of Passengers	One-Hour Time Increment	One- Hour Accumulated Demand
			Start	End				
21FG	*	2:20	2:00	2:20	20	125	N/A	N/A
2(small maco)	*	2:38	2:20	2:38	18	112	N/A	N/A
22FG	*	2:48	2:38	2:48	10	121	2:20 – 3:19	358
21FG	3:17	3:30	3:18	3:30	12	130	2:38 – 3:37	363
2(small maco)	3:32	3:45	3:33	3:45	12	107	2:48 – 3:47	358
22FG	3:41	3:52	3:42	3:52	10	128	3:30 – 4:31	365
21FG	4:20	4:34	4:21	4:34	13	125	3:45 – 4:44	360
2(small maco)	4:37	4:49	4:38	4:49	11	118	3:52 – 4:51	371
22FG	4:43	5:07	4:50	5:07	17	116	4:34 – 5:33	359
21FG	5:20	5:35	5:21	5:35	14	130	4:49 – 5:48	364
2(small maco)	5:41	5:59	5:42	5:59	17	109	5:07 – 6:06	355
22FG	6:18	6:32	6:19	6:32	13	128	5:35 – 6:34	367
21FG	6:30	6:46	6:31	6:46	15	127	5:59 – 6:58	364
2(small maco)	6:54	7:16	6:56	7:16	20	119	6:14 – 7:16	374

N/A – Not Applicable
*Bus already parked before 2 pm at the School Parkto commence afternoon operation

Afternoon operation

The highest passenger per hour loaded at School Park was 374; f is therefore obtained from Equation 1 as $f \geq 374/(55x2) \geq 3.4$ buses/hr.

The headway from Equation 2 is $h = 60/3.4 = 17.6$ min; a 15 minute-headway is therefore used in planning.

From operational data in Table 5 the average travel time is 53 min; tt' = 4 min and tt" = 14 min thus the average Cycle time (T) for afternoon operations is 71 minutes; an available cycle time of 78 minutes is used for the design which gives 7 minutes for damping of variation in schedule.

From Equation 4 the Fleet size is obtained as:

N = nhint (78/15) = 5.2 = 6 buses needed for afternoon operation

Scheduling

Schedules provide essential information to riders, including departure, arrival and trip duration times, which are required to plan a trip. An accurate, efficient and reliable schedule helps to enhance the quality of public service. However, there is presently no such schedule available. Table 7 is the summary of the information used to develop the anticipated service schedules in Table 8 and 9 for morning and afternoon operations respectively.

Table 7: Summary of information for Morning and Afternoon operation service schedules

Morning Operation			
		Travel time:	
Inward-bound Travel Time (T_o')	= 21 min	Terminus – Gate	= 9 min
Outward-bound Travel Time (T_o")	= 21 min	Gate – School Park	= 11 min
Total travel time	= 42 min	School Park – Gate	= 8 min
Layover time at Tanke Terminus (tt')	= 13 min	Gate – Oke-Odo	= 3 min
Layover time at School Park (tt")	= 4 min	Oke-Odo – MFM	= 4 min
Recovery time (t)	= 6 min	MFM – Sanrab	= 3 min
Available cycle time	= 65 min	Sanrab – NNPC	= 3 min
Span of service	= 7:00 – 10:35 am	NNPC – Terminus	= 2 min
Headway	= 13 min		
Afternoon Operation			
		Travel time:	
Outward-bound Travel Time (T_o")	= 27 min	School Park – Gate	= 11 min
Inward-bound Travel Time (T_o')	= 26 min	Gate – Oke-Odo	= 5 min
Total travel time	= 53 min	Oke-Odo – MFM	= 4 min
Layover time at Tanke Terminus (tt')	= 4 min	MFM – Sanrab	= 3 min
Layover time at School Park (tt")	= 15 min	Sanrab – NNPC	= 3 min
Recovery time (t)	= 6 min	NNPC – Terminus	= 2 min
Available cycle time	= 78 min	Terminus -Oke-Odo	= 11 min
Span of service	= 2:00 – 8:20 pm	Oke-Odo – Gate	= 4 min
Headway	= 15 min	Gate – School Park	= 11 min

Travel Demand Forecast

While the outcome of the study as presented in Sections 3.3 and 3.4 is considered as a short-range plan for which immediate implementation is recommended, a demand forecast is made as medium and long-range plan for the administration of the bus transit scheme. Equation 6 was derived from the students' populations for the University for 2013/2014 – 2017/2018 sessions shown in Table 10 using regression analysis (Board of Education – Madison, 2019) and used to project the populations in 2022/2023, 2027/2028 and 2037/2038 i.e. the next 5, 10 and 20 years respectively.

Table 8: Anticipated Bus Schedule for Morning Operation

Trip No	Bus No	Inward-bound			Outward-bound						
		Tanke Terminus	Gate	Sch Park	Sch Park	Gate	Oke-Odo	MFM	Sanrab	NNPC	Tanke Terminus
1	1	7:12	7:17	7:28	7:32	7:40	7:43	7:47	7:50	7:53	7:55
2	2	7:24	7:33	7:44	7:48	7:56	7:59	8:03	8:06	8:09	8:11
3	3	7:36	7:45	7:56	8:00	8:08	8:11	8:15	8:18	8:21	8:23
4	4	7:48	7:57	8:08	8:12	8:20	8:23	8:27	8:30	8:33	8:35
5	5	8:00	8:09	8:20	8:24	8:32	8:35	8:39	8:42	8:45	8:47
6	1	8:12	8:17	8:28	8:32	8:40	8:43	8:47	8:50	8:53	8:55
7	2	8:24	8:33	8:44	8:48	8:56	8:59	9:03	9:06	9:09	9:11
8	3	8:36	8:45	8:56	9:00	9:08	9:11	9:15	9:18	9:21	9:23
9	4	8:48	8:57	9:08	9:12	9:20	9:23	9:27	9:30	9:33	9:35
10	5	9:00	9:09	9:20	9:24	9:32	9:35	9:39	9:42	9:45	9:47
11	1	9:12	9:17	9:28	9:32	9:40	9:43	9:47	9:50	9:53	9:55

12	2	9:24	9:33	9:44	9:48	9:56	9:59	10:03	10:06	10:09	10:11
13	3	9:36	9:45	9:56	10:00	10:08	10:11	10:15	10:18	10:21	10:23
14	4	9:48	9:57	10:08	10:12	10:20	10:23	10:27	10:30	10:33	10:35

Table 9: Anticipated Bus Schedule for Afternoon Operation

Trip No	Bus No	**Outward-bound**							**Inward-bound**			
		Sch Park	Gate	OkeOdo	MFM	Sanrab	NNPC	Tanke Terminus	Tanke Terminus	OkeOdo	Gate	Sch Park
1	1	2:20	2:31	2:36	2:40	2:43	2:46	2:48	2:52	3:03	3:07	3:18
2	2	2:35	2:46	2:51	2:55	2:58	3:01	3:03	3:07	3:18	3:22	3:33
3	3	2:50	3:01	3:06	3:10	3:13	3:16	3:18	3:22	3:33	3:37	3:48
4	4	3:05	3:16	3:21	3:25	3:28	3:31	3:33	3:37	3:48	3:52	4:03
5	5	3:20	3:31	3:36	3:40	3:43	3:46	3:48	3:52	4:03	4:07	4:18
6	6	3:35	3:46	3:51	3:55	3:58	4:01	4:03	4:07	4:18	4:22	4:33
7	1	3:50	4:01	4:06	4:10	4:13	4:16	4:18	4:22	4:33	4:37	4:48
8	2	4:05	4:16	4:21	4:25	4:28	4:31	4:33	4:37	4:48	4:52	5:03
9	3	4:20	4:31	4:36	4:40	4:43	4:46	4:48	4:52	5:03	5:07	5:18
10	4	4:35	4:46	4:51	4:55	4:58	5:01	5:03	5:07	5:18	5:22	5:33
11	5	4:50	5:01	5:06	5:10	5:13	5:16	5:18	5:22	5:33	5:37	5:48
12	6	5:05	5:16	5:21	5:25	5:28	5:31	5:33	5:37	5:48	5:52	6:03
13	1	5:20	5:31	5:36	5:40	5:43	5:46	5:48	5:52	5:03	6:07	6:18
14	2	5:35	5:46	5:51	5:55	5:58	6:01	6:03	6:07	5:18	6:22	6:33
15	3	5:50	6:01	6:06	6:10	6:13	6:16	6:18	6:22	5:33	6:37	6:48
16	4	6:05	6:16	6:21	6:25	6:28	6:31	6:33	6:37	5:48	6:52	7:03
17	5	6:20	6:31	6:36	6:40	6:43	6:46	6:48	6:52	6:03	7:07	7:18
18	6	6:35	6:46	6:51	6:55	6:58	7:01	7:03	7:07	6:18	7:22	7:33
19	1	6:50	7:01	7:06	7:10	7:13	7:16	7:18	7:22	6:33	7:37	7:48
20	2	7:05	7:16	7:21	7:25	7:28	7:31	7:33	7:37	6:48	7:52	8:03
21	3	7:20	7:31	7:36	7:40	7:43	7:46	7:48	7:52	8:03	8:07	8:18

Equations 1 – 4 were thereafter used to forecast the demand shown in Tables 11 and 12. Table 11 is based on a design load factor of 2. Table 12 shows the demand based on a design load factor of 1.2 and is recommended to be the considered option by the transport agency for the medium- and long-term planning. It should be noted that there is no specified maximum load factor in literature as load factor is a policy of the transit agency. It is observed that the headway thins out to 4 minutes by 2027/2028 session which indicates that the bus as a vehicle may no longer be an adequate and efficient carrier along the route after 2027/2028. Therefore, there may be the need to introduce such vehicles as Light Rail Transit (LRT) that can convey more riders or have Bus Rapid Transit (BRT) on dedicated lanes to reduce the cycle time. A consideration could also be given to accommodate more students' population residency on the campus.

Table 10: Students Population of University of Ilorin

Year	Population
2013/2014	38759
2014/2015	46606
2015/2016	52424
2016/2017	54894
2017/2018	56718

Source: Annual Report (2014, 2015, 2016, 2017, 2018)

$$y = 4420.6x + 36618 \quad [6]$$

where y = population and x = number of years

Table 11: Projected travel demand at load factor of 2.0

Year	Population	Morning Operation				Afternoon Operation			
		Demand (pers/hr)	Freq (bus/hr)	Headway (min)	Fleet size	Demand (pers/hr)	Freq (bus/hr)	Headway (min)	Fleet size
2022/2023	80825	666	6.1	9	8	533	4.9	12	7
2027/2028	102928	848	7.8	7	10	679	6.2	9	9
2037/2038	147134	1212	11.1	5	13	971	8.9	6	13

Table 12: Projected travel demand at load factor of 1.2

Year	Population	Morning Operation				Afternoon Operation			
		Demand (pers/hr)	Freq (bus/hr)	Headway (min)	Fleet size	Demand (pers/hr)	Freq (bus/hr)	Headway (min)	Fleet size
2022/2023	80825	666	10.1	5	13	533	8.1	7	12
2027/2028	102928	848	12.9	4	17	679	10.3	5	16
2037/2038	147134	1212	18.4	3	22	971	14.8	4	20

Conclusion

An immediate measure that should be taken to enhance the transit scheme is to introduce 2 additional buses to make 5 buses for the morning operation and 3 additional vehicles for the afternoon operations to make 6 buses. A schedule of the movements of the vehicles should also be made available to commuters to enhance trip planning. The projected travel demand forecast showed that in ten years the headway needed to meet travel demand reduces to 4 minutes. Thus, vehicle of larger capacity such as monorails, light rails should be considered in long term planning for movement along the corridor. BRT on dedicated lanes can also be considered to reduce the cycle time. Another option is to encourage higher students' residency on campus. A reserve bus also needs to be added to the total fleet size as vehicles will be serviced either preventatively or because they have broken down. As a rule, a reserve fleet is about 10% of the total fleet needed to provide the service (BRT Planning Guide, 2017).

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