A MODEL FOR EVALUATING POTENTIAL SITES FOR BUS GARAGES IN A DEVELOPING COUNTRY

DR. A. BABALOLA
TECHNICAL SERVICES DIVISION
NIGERIAN PORTS PLC
26/28 MARINA LAGOS

ABSTRACT

In a developing country like Nigeria, mass transit development is still at a rudimentary level. The transit supply far lags transit demand, and there is the propensity to increase the fleet-size of all the State Transit Corporations remarkably beyond the existing situation. This tendency indicates that the existing bus garages may have to be expanded or relocated depending on their design capacity and permanence of bus garages. Transit Planners need obviously a planning tool to do this effectively. Hence, the paper attempts to develop a mathematical model as a planning tool for evaluating potential sites for bus garages where there is paucity of data. It considers the total annual cost of deadheading and land acquisition. The Beta probability density functions are used in modelling, and geometric locations of deadheads are considered among other variables in deadheading cost modelling. A case study of Ilorin transit system is considered to illustrate the application of the total annual cost model of a bus garage location. Some useful results are obtained and interpreted.

1.0 INTRODUCTION

The economic depression has informed the government of a developing country, such as Nigeria, of the need to revitalise the mass transit industry for both captives and choice riders. As a result, the government of Nigeria embarked on a nation-wide mass transit programme about two years ago. Each State of the federation now has its own Mass Transit Corporation to implement the national directive in this respect. Incidentally, the transit supply far lags transit demand in all states, and each state corporation has its bus garages located on either temporary or permanent sites.

In view of the soaring demand for transit service in the country, there is tremendous need for each corporation to increase its fleet-size of buses, and in the longrun, some of the existing permanent garages will be expanded at the same location or a new location, while those on temporary sites will move to more permanent locations. All these garages are usually located on ad-hoc basis in developing countries.

Location of bus garages in a developed nation is much more complex, and the following factors are often considered according to Waters et al (1986): road network configuration, bus route structure, location of deadhead for each route, bus dispatching policies; availability of land and cost; and costs of operation, construction and maintenance of buses, etc. While human judgement can prevail on the intangible factors, analytical models have proved useful in relating the tangible factors together. Both human judgement and analytical approach will enable transit planners to assess and select near-optimal sites for locating bus garages. Waters et al have developed a non-linear optimization model of the total cost of deadheading, incident cost, garage operating cost and cost of land, and applied it to the city of Calgary Transit system, Canada.

Tind (1981) has developed a linear programming model that considers the capacity of bus garages and cost of deadheading to evaluate seven district potential sites for a bus garage in Aarhus, C., Denmark. Maze (1984) has been involved in modelling location of bus garages in a number of studies, and from experience, he has suggested that both routes and location of bus garages should be done simultaneously to avoid or minimise location or relocation problem.

The bus transit systems in developed nations are obviously sophisticated and so are the data banks required to calibrate these models. However, in a developing nation where there is paucity of data, a model that requires small data bank will suffice. It is in this vein that a discrete model of the total cost of land and deadheading or non-revenue distance has been developed and applied to the city of Ilorin Transit system to illustrate its capability.

2.0 DISCRETE MODEL DEVELOPMENT

Consider the hypothetical bus transit network of a city transit system shown in Figure 1. The polar coordinate of the centre of the city is 0(o,o). Let the polar coordinate of a deadhead be D_j (r_j, Θ_j) where, j = 1, 2, 3 .... m and m is the number of deadheads in the transit network. If there are n bus routes on the system, then $m \leq n$ because it is all too common to find a deadhead connecting two or more routes. The converse is never true. Let the bus garage for the system be located at G $(R, \emptyset)$ and Ro be the maximum reasonable value of R.

In view of the above geometric configuration, a model which enables the near-optimal values of R and $\emptyset$ to be determined for given values of r_j θ_j and Ro is developed as follows to minimize the cost of land acquisition and non revenue or deadheading distance for the entire system.

2.1 DEADHEADING OR NON-REVENUE DISTANCE COST MODEL

At the beginning of the daily operation of any urban transit system, empty buses are often dispatched from the bus garage (where buses are stored and serviced) to various deadheads and are returned to the same garage at the end of the day. Consequently, non-revenue distances are covered at the expense of the authority responsible for managing the operation as deadheading cost. Therefore, it is the objective of the authority to locate the bus garage as close as possible to these deadheads in order to minimize this cost.

There are three theoretical patchs for deadheading in transit networks: a - airline path, g - gridiron path and c - curved path as shown in Figure 1. The choice of a path depends of the road network configuration. The deadheading distance dj can be expressed as

$$d_j(R) = \lambda [R^2 + r_j^2 - 2r_j R \cos(\theta_j - \emptyset)]^{\frac{1}{2}} \quad ..(1)$$

where, $\lambda = 1.0$ for airline path

$\lambda \geq 1.4$ for gridiron path

$1.0 < \lambda < 1.4$ for curved path

If N_j buses are dispatched to deadhead Dj per day, tj days of operation per year and Pj deadheading trips per day, then the total non-revenue distance per year for the entire system is

$$d(R) = \sum_{j=1}^{m} N_j t_j P_j d_j \quad \ldots\ldots\ldots (2)$$

Assuming γ_d is cost of deadheading per kilometer of non-revenue distance, then the total annual cost of deadheading is

$$Cd^{(R)} = \gamma_d \sum_{j=1}^{m} N_j t_j P_j d_j \quad \ldots\ldots (3)$$

Equation (3) can be simplified (with tj = t and P = P) as

$$Cd^{(R)} = \gamma_d \lambda \bar{P} \bar{t} \sum_{j=1}^{m} N_j [R^2 + r_j^2 - 2r_j R \cos(\theta_j - \emptyset)]^{\frac{1}{2}} \quad \ldots\ldots (4)$$

2.2 LAND ACQUISITION COST MODEL.

The cost of land acquisition varies radially as one moves away from the centre of the city. That is, the unit cost of land is a function of R and $\emptyset$. The unit cost of land is the discounted cost of a square metre of land per year. This cost is not easy to estimate as a comprehensive data is required. In the absence of huge data banks, Law and Helton (1982) have suggested that Beta (α_1 α_2) probability density function provides a great deal of curves which can be used in modelling. Nine different shapes of Beta curves are presented in Figure 2. In formulating the unit cost function, it is assumed that the minimum unit cost (a) and maximum unit cost (b) can be easily identified for any given sector and that the analyst has a feel for the shape of curve that represents the variation of cost of land in that region. It should be emphasized that in this model, the shape of Beta curve is more relevant than its probabilistic attribute.

The general Beta function is expressed as

$$f(x) = \frac{x^{\alpha_1 - 1} (1 - x)^{\alpha_2 - 1}}{B(\alpha_1, \alpha_2)}$$

$$0 \leq X \leq 1 \quad \ldots\ldots (5)$$

where, $B(\alpha_1, \alpha_2) = \frac{\sqrt{(\alpha_1)}\sqrt{(\alpha_2)}}{\sqrt{(\alpha_1 + \alpha_2)}}$

The unit cost of land can be formulated as

$\gamma_c(x) = a(1 + K f(x))$

where a = minimum unit cost of land

k = a modifying factor depending on the maximum unit cost

If b is the maximum cost and if Z is the maximum value of f(x), then

$$b = a(1 + k Z)$$

$$k = \frac{b - a}{az} \quad \ldots\ldots\ldots 7$$

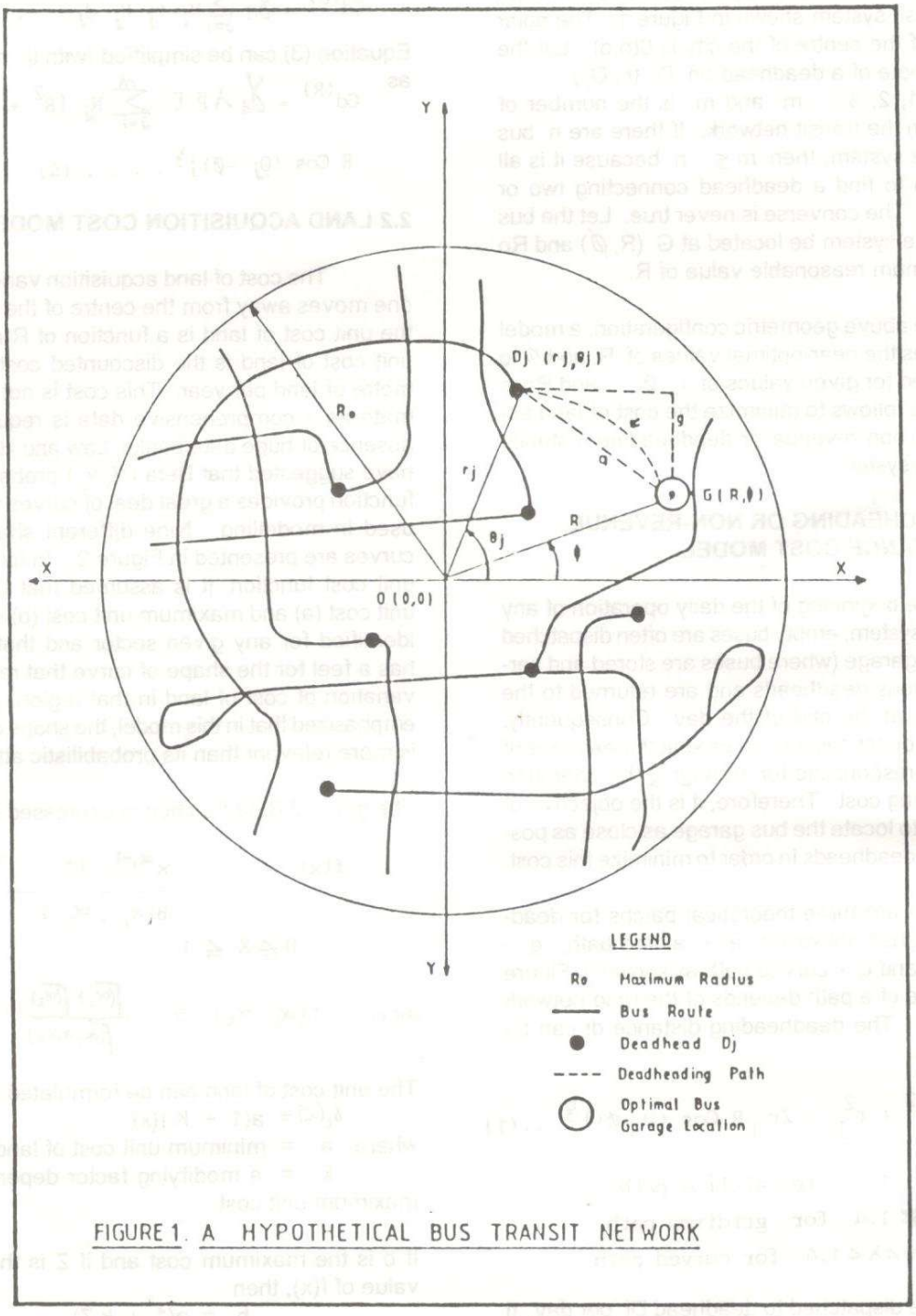


FIGURE 1. A HYPOTHETICAL BUS TRANSIT NETWORK

Thus, equation (7) enables the value of K to be estimated for any given region. Sinc x is the non-dimensionless random variable for Beta function, then x=R/Ro where R is the random variable for the models. Therefore, equation (6) becomes,

$$\gamma_1 (R) = a [1+Kf(R)] \text{ for } 0 \leq R \leq R_o \quad \ldots(8)$$

where Ro is the furthest distance at which the bus garage can be located within a city.

Now that the unit cost of land has been formulated, the cost of land acquisition still depends on the size or capacity of the garage to be located. The empirical study by Waters et al (1986) shows that the gross area (A) of a garage is a linear function of the fleet size (N). That is,

$$A = B_o + B_1 N \quad \ldots\ldots\ldots\ldots 9$$

B_o = minimum space required for parking private vehicles and administration

B_1 = required space per bus at the garage for parking, maintenance and bus manoeuvres.

Infact, Waters et al have studied 16 garages with 16 to 250 buses and calibrated equation (9) as

$$A = 533 + 94.25N$$
$$r^2 = 0.937$$

While ΣNj is the total number of vehicles operating daily, the fleet size (N) of any transit authority should at least be equal to it. i.e.

$$N \geq \sum_{j=1}^{m} Nj$$

or

$$N = No + \sum_{j=1}^{m} Nj \quad \ldots\ldots\ldots \quad (11)$$

where No = number of grounded and reserved buses Hence, the Annual Cost of land acquisition for any garage is $C_1(R) = \gamma_1(R) A$

$$C_1(R) = a[1+Kf(R)] [Bo + B_1N] \text{ for } 0 \leq R \leq RO \ldots\ldots\ldots\ldots\ldots (12)$$

2.3 TOTAL ANNUAL COST MODEL

The total annual cost of a bus garage location is the sum of annual cost of deadheading distance and annual cost of land acquisition.

i.e. $C_T(R) = C_d(R) + C_1(R)$

$$C_T(R) = \gamma_d \lambda \bar{p} \sum_{j=1}^{m} N_j [R^2 + r_j^2 - 2r_j R \cos(\theta_j - \emptyset)]^{\frac{1}{2}} + a [1 + K f(R)] [Bo + B_1 N] \quad \ldots(13)$$

$$\text{for } 0 \leq R \leq R_o$$

This total annual cost can be minimized provided

$$\frac{\partial C_T(R)}{\partial R} = \frac{\partial C_d(R)}{\partial R} + \frac{\partial C_1(R)}{\partial R} = 0$$

and

$$\frac{\partial^2 C_T(R)}{\partial R^2} > 0 \quad \text{i.e.} \quad \frac{\partial^2 C_d(R)}{\partial R^2} + \frac{\partial^2 C_1(R)}{\partial R^2} > 0$$

The above conditions should be tested for optimality mathematically. However, in view of the discrete and complex nature of the annual total cost model, it is better to evaluate and plot the function itself and hence, determine the near - optimal global location (R*) for the bus garage for known values of $\emptyset$ where possible.

However, where several potential garage sites, with known values of R and O, have been selected, the annual total cost function can be evaluated for each site and be used subsequently to rank the sites. At this point, it is clear that the model can be applied in two ways: to determine the optimal location of a garage with known bearing, and to evaluate the cost of garages with definite locations and bearings. The former is illustrated in section 3.0 with the city of Ilorin transit network as a case study.

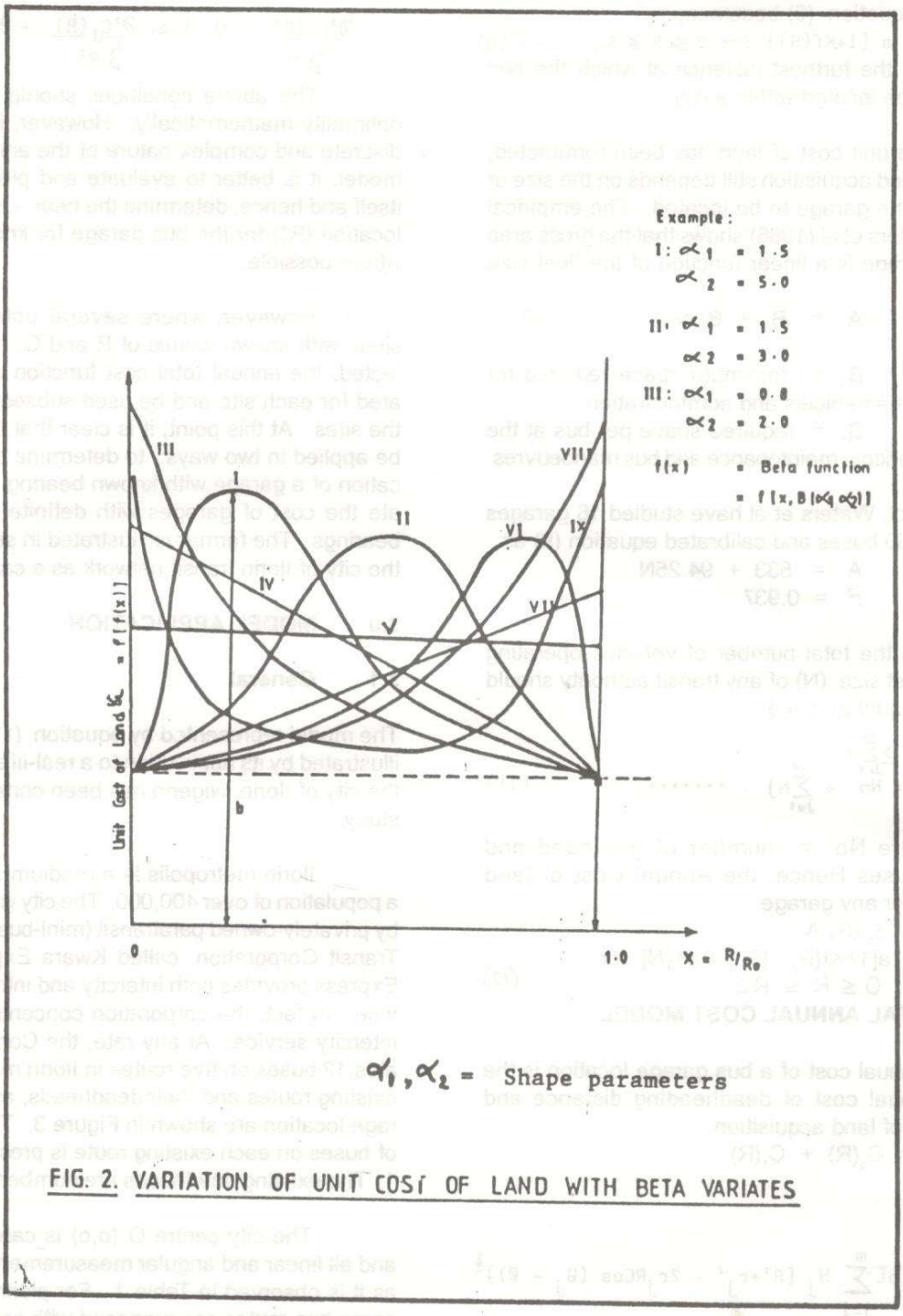
3.0 MODEL APPLICATION

3.1 General

The model represented by equation (13) can be best illustrated by its application to a real-life problem; and the city of Ilorin, Nigeria has been considered a case study.

Ilorin metropolis is a medium-sized city with a population of over 400,000. The city is served largely by privately-owned paratransit (mini-buses) and Kwara Transit Corporation, called Kwara Express. Kwara Express provides both intercity and intra-city bus service. In fact, the corporation concentrates more on intercity service. At any rate, the Corporation operates 12 buses on five routes in Ilorin metropolis. The existing routes and their deadheads, and the bus garage location are shown in Figure 3. The distribution of buses on each existing route is presented in Table 1. The existing deadheads are numbered from 1 to 5.

The city centre O (o,o) is carefully selected and all linear and angular measurements are tied to it as it is observed in Table 1. For planning purposes, some bus routes are proposed with broken lines and five additional deadheads (represented by small solid triangles) are generated for the exercise, and are shown in Figure 3.



α_1, α_2 = Shape parameters

FIG. 2. VARIATION OF UNIT COST OF LAND WITH BETA VARIATES

TABLE 1 DEADHEADS PARAMETERS

j	r_j (m)	θ_j	Existing N_j	Proposed N_j
1	690	0^o	4	30
2	720	330^o	4	30
3	900	125^o	2	15
4	840	125^o	1	15
5	780	140^o	1	15
6	540	260^o	–	15
7	1290	300^o	–	15
8	750	310^o	–	15
9	990	065^o	–	15
10	600	230^o	–	15
			12	120

The total number of buses in operation is increased to 120 and dispatched to these deadheads as presented in Table 1 with their respective parameter. The main objective of the problem is to find the optimal global location for garage. This objective is broken down as follows:

i) To estimate the cost of the existing garage location for the proposed transit service network.
ii) To evaluate the optimal location, if any, for a bus garage in the same direction with the existing one.
iii) To evaluate the optimal location and cost of three alternative bus garages within the metropolis.
iv) To rank all the four sites according to their total cost of land and deadheading.

The first step to take in order to achieve all these objectives is to estimate the bearings of four garages including the existing one. As a result, the following are data obtained:

i	Alternative Area	Bearing (Øi)
1.	Offa Park (Existing)	295°
2.	Asa Dam (Proposed)	230°
3.	Sobi Hill (Proposed)	080°
4.	Oloje (Proposed)	130°

These alternatives are represented by four radial lines emanating from the city centre, along which bus garages are to be located.
Next, the value of the necessary parameters in the model are estimated as follows:

(i) Fleet size:

$\sum_{j=1}^{M} N_j$ = 120 buses
No = 25% $\sum_{j=1}^{M} Nj$
N = 150 buses

(ii) Unit cost of deadheading:
fuel consumption rate of buses = 0.301/km
cost of diesel = 0.34 ₦/1
operating cost = 0.102 ₦/km
∴ Unit deadheading cost, δ_d = 0.102 ₦/km

(iii) Unit cost of land:

cost of 50mx50m plot = ₦1,000 - ₦30,000
cost of land = ₦0.4 - ₦12.0/m2
design period = 25 years
discount rate = 20%
capital recovery Factor (CRF)= 0.2021

annual unit cost of land = 0.08 - 2.4 N/m²/yr
∴ minimum unit cost, a = 0.08 N/m²/yr
∴ maximum unit cost, b = 2.4 N/m²/yr

iv) Space requirement:
Bo = 533 m²
B1 = 94.25 m²/bus
∴ A = 14,670.5m² ≈ 100m x 150m plot

v) Size of city:
Ro = 5km

vi) Approximate Beta function values:
(From Law and Kelton (1982) (The errors associated with the truncated values are practically insignificant).

R(Km)	X=R/Ro
0	0
0.5	0.1
1	0.2
2	0.4
3	0.6
4	0.8
5	1.0

Case I α_1=1.5 α_2=5.0	Case II α_1=1.5, α_2=30	Case III α_1=0.8, α_2=2.0
0	0	0
2.8	1.6	2.1
2.5	1.8	1.5
1.0	1.4	1.0
0.25	0.8	0.7
0.1	0.3	0.3
0	0	0
Z = 2.8	Z = 1.8	Z = 3.0
K = 10.4	K = 16.1	K = 9.7

vii) Bus Operation:
Road network $\lambda \geq 1.40$
dispatching policy, $\bar{p}$ = 2 trips (to and from deadhead)
days of operation/year, $\bar{t}$ = 365

3.2 Annual Cost of Deadheading:

The model for the annual cost of deadheading i.e. equation (4) can be simplified using some of the above values as

$$C_d(R) = 104.2 \left[\sum_{j=1}^{m} Z_j(R)\right]$$

$$\text{where } Z_j(R) = N_j \left(R^2 + r_j^2 - 2 r_j R \cos(\theta_j - \phi_i)\right)^{1/2}$$

The value of $Z_j(R)$ for O R 5 and j = 1,2.,10 for each ϕ_i (i=1,2 ...4) is evaluated and hence, four values of $C_d(R)$ are obtained for the problem. A typical table for computing the annual deadheading cost is presented in Table 2 for ϕ = 295o. The summary of all the deadheading cost is presented in Table 3.

3.3 Annual Cost of Land

Three beta functions are considered resulting in 3 cases. The choice of any Beta function, as discussed previously, depends on the factual variation-Variation cost of land acquisition in any direction where a bus garage is to be located. So, these 3 cases represent the actual variation cost of land in Ilorin are obtained for illustration purposes.

Case i : $C_1(R) = 1174\ [1+10.4\ f(R)]$
Case ii : $C_1(R) = 1174\ [1+16.1\ f(R)]$
Case iii : $C_1(R) = 1174\ [1+9.7\ f(R)]$

These equations are evaluated and the results are presented in Table 4.

3.4 Annual Total Cost

The annual total cost (equation 13) is the systematic summation of Tables 3 and 4, and it is presented in Table 5. The values are plotted in Figure 4,5 and 6 for Cases i, ii, and iii respectively. Now, the objectives highlighted previously can be addressed with these graphs plotted for our garages.

Objective (i):

The existing garage is located at 2.55km away from the centre at 295° bearing, with the angle measured anti-clockwisely from the x - axis. The annual cost of the existing garage (alternative) for the proposed transit network is N53,000, N68,000 and N56,500 for cases i, ii and iii respectively.

Objective (ii)

While case ii indicates non-optimal condition, there are optimal locations in cases i and iii. Case i shows that the optimal location for a garage in the same direction as the existing one is 2.0km, which is not far from the existing garage located at 2.55km away from the city centre. the optimal location for same is 1.0km in case iii.

Objective (iii)

The optimal location for all the three alternatives are the same as in (ii) above. However, the annual total cost varies: the optimal cost of alternative 2 is N55,000 and N41,500 in cases i and iii respectively; the optimal cost of alternative 3 is N52,000 and N40,000 in cases i and iii respectively; and the optimal cost of alternative 4 is N55,000 and N42,500 in cases i and iii respectively

Objective (iv)

On the basis of (ii) and (iii) above, alternative 4 is the most expensive of all sites, followed by alternatives 2 and 3, while alternative 1 is the cheapest.

The optimum locations of bus garages are shown in Figure 3 for the four alternatives. However, the final selection of any optimal location still depends on availability of land. From the foregoing analysis, it is clear that the model can be used to evaluate suitable sites for bus garages, and to determine the optimal location of a bus garage where it exists.

TABLE 2 A TYPICAL DEAD-HEADING COST COMPUTATION ($\phi_i = 295^o$)

J	Y_j(KM)	N_j	θ_j(o)	$\cos(\theta_j - \phi_i)$	$Z_j(0)$	$Z_j(1)$	$Z_j(2)$	$Z_j(3)$	$Z_j(4)$	$Z_j(5)$
1	0.69	30	0	0.42	20.7	28.4	54.6	83.4	112.9	142.5
2	0.72	30	330	0.82	21.6	17.4	44.1	73.3	103.0	132.9
3	0.90	15	125	-0.98	13.5	28.4	43.7	58.3	73.3	88.3
4	0.84	15	125	-0.98	12.6	27.5	42.4	57.4	72.4	87.4
5	0.78	15	140	-0.91	11.7	26.1	40.9	55.9	70.8	85.4
6	0.54	15	260	0.82	8.1	9.6	23.6	38.6	53.6	68.5
7	1.29	15	300	0.996	19.4	4.6	10.9	25.8	40.8	55.8
8	0.75	15	310	0.97	11.3	4.9	19.2	34.2	49.2	64.1
9	0.99	15	65	-0.64	14.9	27.0	41.1	55.7	70.4	85.3
10	0.60	15	230	0.42	9.0	13.9	27.5	42.0	56.8	71.7
$Z_j(R)$					142.8	187.8	348.2	524.6	703.2	882.3
Cd(R) x 10^3 ₦/yr					14.9	19.6	36.3	54.7	73.3	91.9

TABLE 3 ANNUAL DEADHEADING COST C_d (R)(₦'000)

	RADIAL LOCATION R (km)					
BEARING ϕ_i	0.o	1.0	2.0	3.0	4.0	5.0
295°	14.9	19.6	36.3	54.7	73.3	91.9
230°	14.9	24.1	41.2	59.2	77.5	96.1
080°	14.9	21.5	38.3	56.5	74.9	93.5
130°	14.9	23.2	41.1	59.6	78.2	96.9

TABLE 4 ANNUAL LAND COST $C_1(R)$ (₦ '000)

CASE/BETA FUNCTIONS	GARAGE LOCATION R (KM)					
CASE	0	1.0	2.0	3.0	4.0	5.0
I $\alpha_1 = 1.5$ $\alpha_2 = 3.0$	1·2	31.7	13.4	4.2	2.4	1.2
II $\alpha_1 = 1.5$ $\alpha_2 = 5.0$	1.2	35.2	27.6	16.3	6.8	1.2
III $\alpha_1 = 0.8$ $\alpha_2 = 2.0$	35.3	18.3	12.6	9.1	4.6	1.2

TABLE 5 TOTAL ANNUAL COST $C_t(R)$ (₦ '000)

BEARING		GARAGE LOCATION R (KM)					
i	ϕ_1	0	1.0	2.0	3.0	4.0	5.0
(a) CASE I : $\alpha_1 = 1.5$ $\alpha_2 = 3.0$							
1	250°	16.1	51.3	49.7	58.9	75.6	93.1
2	230°	16.1	55.8	54.6	63.4	79.9	97.3
3	080°	16.1	53.2	51.7	60.7	77.3	94.7
4	130°	16.1	54.9	54.5	63.8	80.6	98.1
(b) CASE II : $\alpha_1 = 1.5$ $\alpha_2 = 5.0$							
1	295°	16.1	54.8	63.9	71.0	80.1	93.1
2	230°	16.1	59.3	68.8	75.5	84.3	97.3
3	080°	16.1	56.7	65.9	72.8	18.7	94.7
4	130°	16.1	58.4	68.7	75.9	85.0	98.1
(c) CASE III : $\alpha_1 = 0.8$ $\alpha_2 = 2.0$							
1	295°	50.2	37.9	48.9	63.8	77.9	93.1
2	230°	50.2	42.4	53.8	86.3	82.1	97.3
3	080°	50.2	42.4	53.8	86.3	82.1	94.7
4	130°	50.2	41.5	53.7	68.7	82.8	98.1

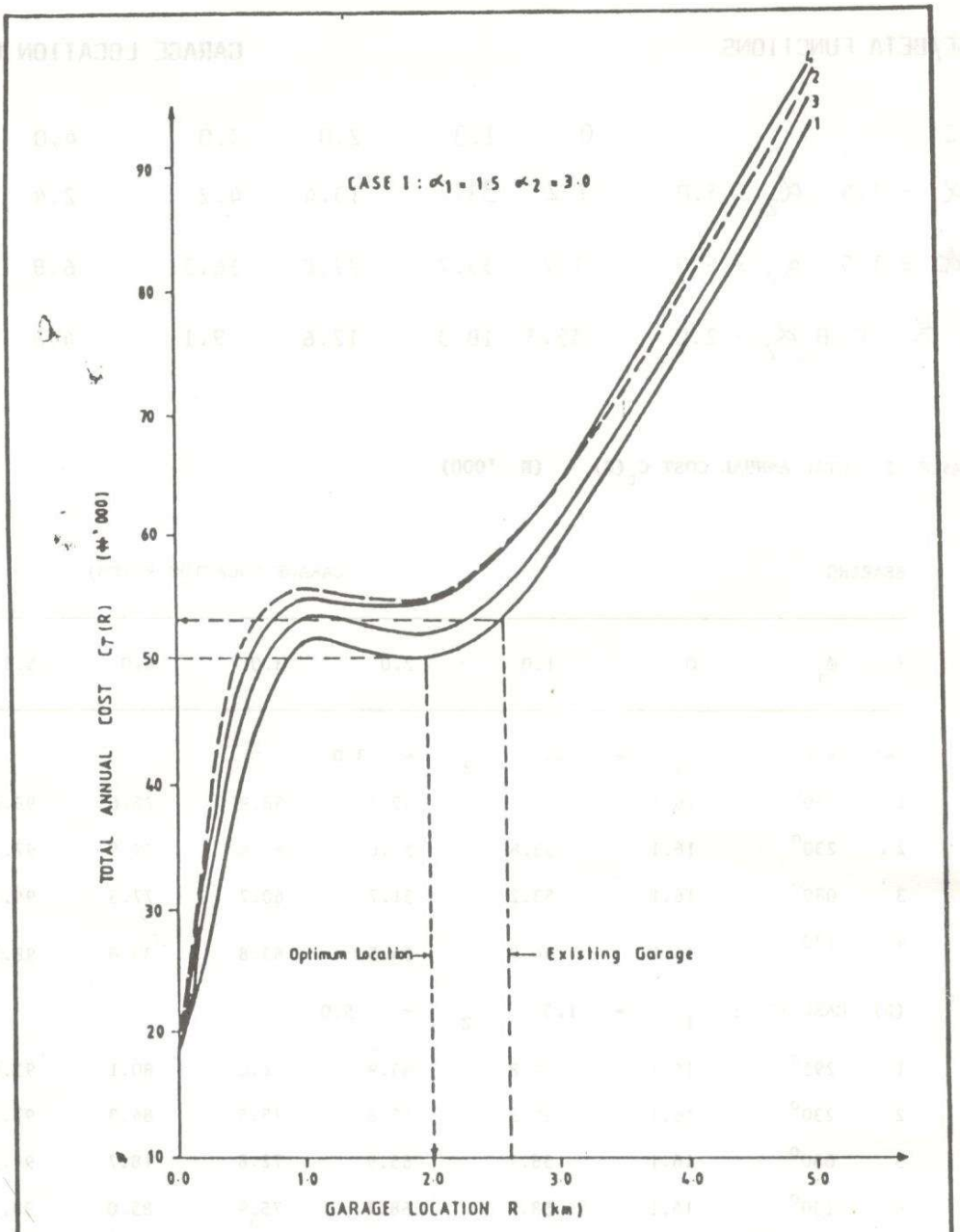


FIG. 4. TOTAL COST FUNCTIONS FOR FOUR GARAGES UNDER CASE 1

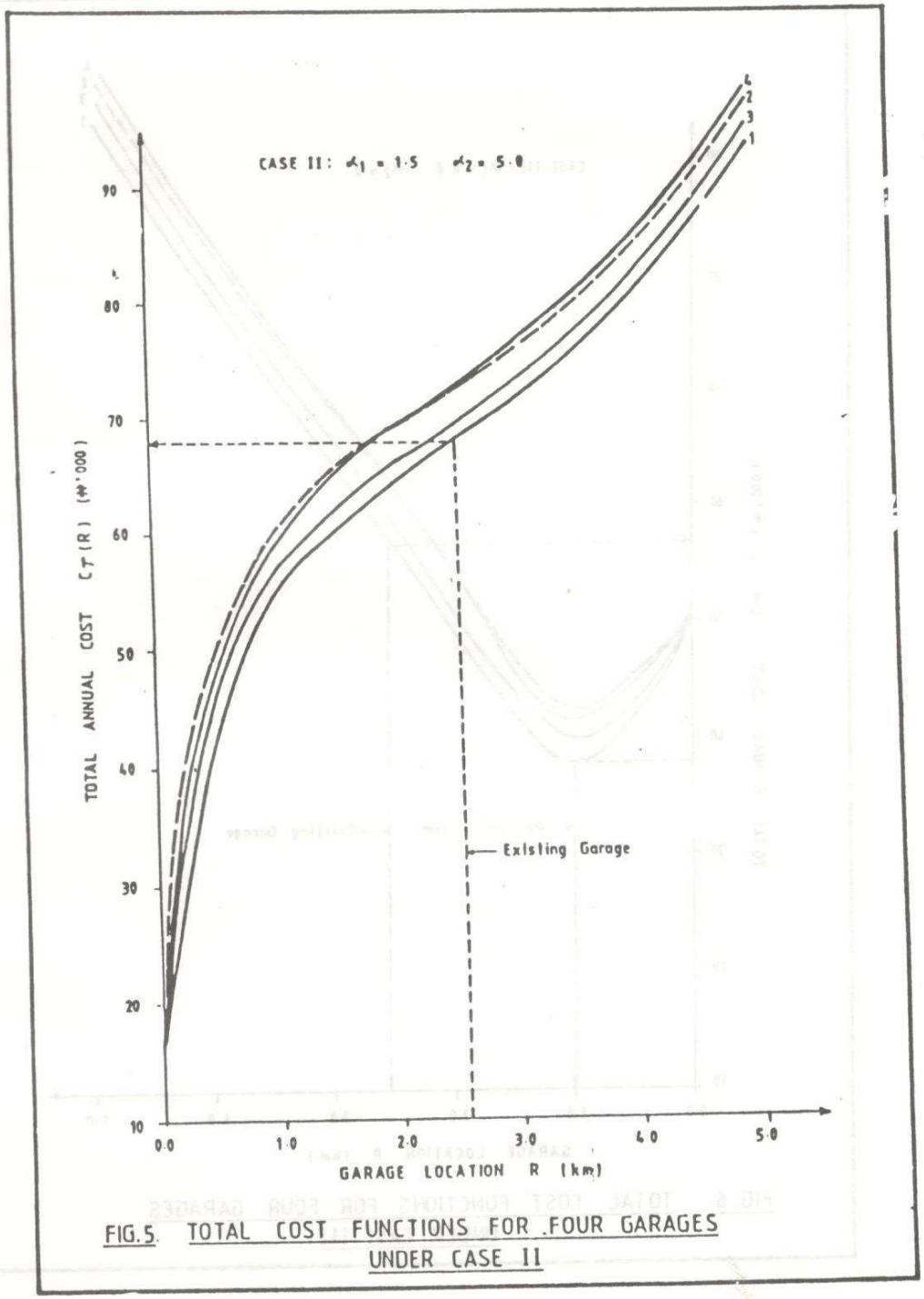


FIG.5. TOTAL COST FUNCTIONS FOR FOUR GARAGES UNDER CASE II

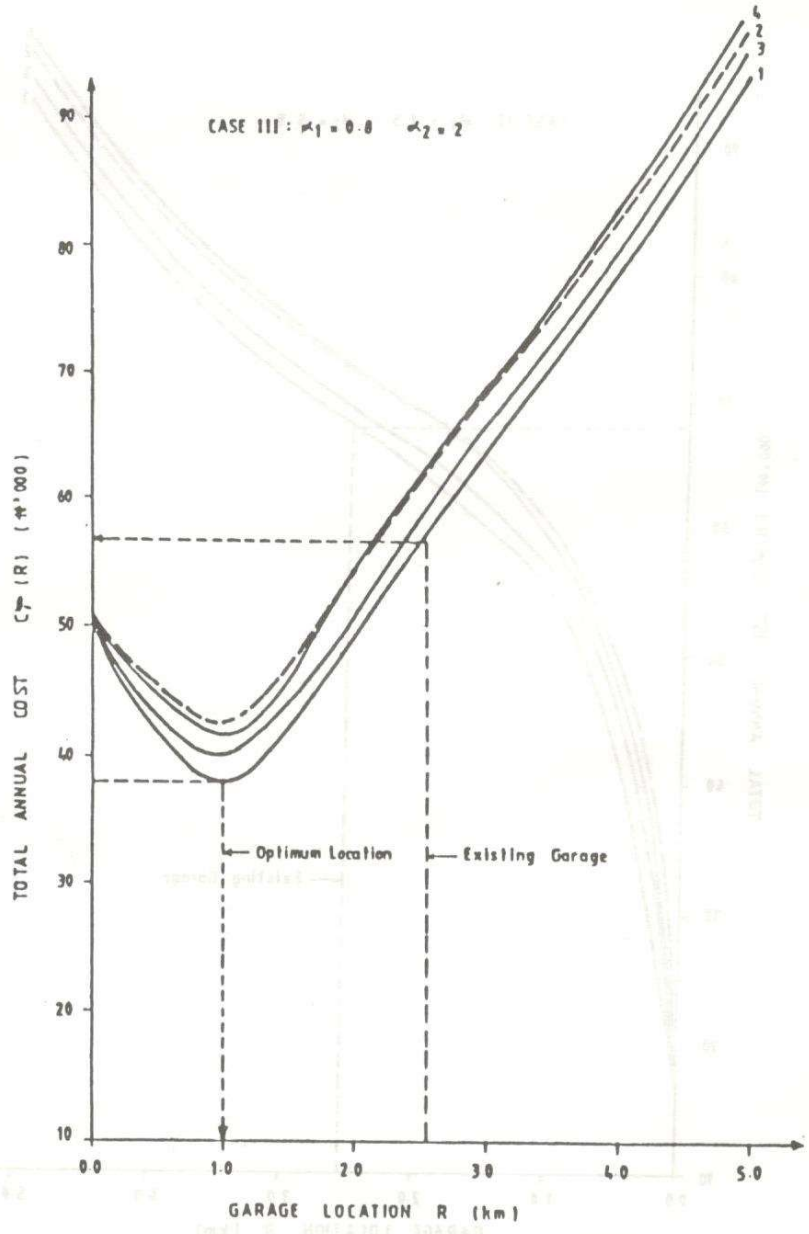


FIG. 6. TOTAL COST FUNCTIONS FOR FOUR GARAGES UNDER CASE III

4. CONCLUSIONS

A model for evaluating suitable sites for bus garages in a developing country, where relevant meticulous or accurate data do not exist, has been developed by considering only two tangible factors that influence bus garage locations. These are annual cost of deadheading or non-revenue distance, which is usually covered at the beginnig and the end of daily transit operation, and annual cost of land acquisition.

The road network bus dispatching policty, geometric location of deadheads and unit cost of deadheading are some of the major parameters of the annual deadheading cost model. Whereas, the land models is largely influenced by beta density function, fleetsize, minimum and maximum unit cost of land. The model for evaluationg different sites for bus garages is the sum of cost of deadheading and land acquisition.

The application of the model is illustrated by considering the city of Ilorin as a case study. It is shown that optimal location of bus garages may or may not exist depending on the choice of Beta function and perhaps, the nature of the deadhead configurations and loads. For all the cases considered, the further away the bus garage is from the city centre, the more costly it is. A closer look at this variation shows that the cost of load is cheaper as one moves away from the city centre whereas, the cost of deadheading increases. But the overall cost increases.

Further research effort should concentrate on sensitivity tests on the main parameters and applications of the model developed above.

NOTATIONS

Dj	=	deadhead J
rj	=	radial location of deadhead J
	=	angular position of deadhead J
m	=	number of deadheads
n	=	number of bus routes
G	=	bus garage
R	=	radial location of a bus garage
	=	angular position of a bus garage
R_o	=	maximum reasonable value of R
d_j	=	jth deadheading distance
	=	Road Network Modifier
N_j	=	number of buses dispatched to deadhead j
P	=	number of non-revenue trips to deadhead
t	=	number of days of operation per year
	=	unit cost of deadheading per vehicle - km
Cd	=	annual cost of deadheading
f(x)	=	Beta function with parameter (
	=	unit cost of land acquisition per m^2 per year
a	=	Minimum unit cost of land
b	=	maximum unit cost of land
Z	=	maximum value of f(x)
k	=	a Beta function modifier
A	=	Gross area of a garage
N	=	fleetsize of a garage
B_o,B_1	=	constants for estimating A
C_l	=	annual cost of land
C_T	=	total annual cost of garage

REFERENCES

Maze T.H. (1984), "The Importance of Simultaneous Consideration of Bus Garage Location and Vehicle Assignment", I.T.E. Journal, November pp. 13 - 15.

Law A.M. & Kelton W.D. (1982). "Simulation Modeling and Analysis", MacGraw-Hill Book Company New York.

Tind, J. (1981), "Location of Bus Depots", Proceeding International Symposium on Location Decisions. Skodsborg, Denmark pp. 402 - 411.

Waters, N.M., Wirasinghe, S.C., Babalola, A. & Marion K.E.D. (1986). "Location of Bus Garages", Journal of Advanced Transportation Vol. 2 No. 1 pp. 135 - 150.

TABLE 5 TOTAL ANNUAL COST $C_T(R)$ (₦ '000)

(a) CASE I : $\alpha_1 = 1.5$ $\alpha_2 = 3.0$

BEARING		GARAGE LOCATION R (KM)					
i	ϕ_i	0	1.0	2.0	3.0	4.0	5.0
1	295°	16.1	51.3	49.7	58.9	75.6	93.1
2	230°	16.1	55.8	54.6	63.4	79.9	97.3
3	080°	16.1	53.2	51.7	60.7	77.3	94.7
4	130°	16.1	54.9	54.5	63.8	80.6	98.1
(b)	CASE II : $\alpha_1 = 1.5$ $\alpha_2 = 5.0$						
1	295°	16.1	54.8	63.9	71.0	80.1	93.1
2	230°	16.1	59.3	68.8	75.5	84.3	97.3
3	080°	16.1	56.7	65.9	72.8	81.7	94.7
4	130°	16.1	58.4	68.7	75.9	85.0	98.1
(c)	CASE III : $\alpha_1 = 0.8$ $\alpha_2 = 2.0$						
1	295°	50.2	37.9	48.9	63.8	77.9	93.1
2	230°	50.2	42.4	53.8	86.3	82.1	97.3
3	080°	50.2	39.8	50.9	65.6	79.5	94.7
4	130°	50.2	41.5	53.7	68.7	82.8	98.1