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Full Length Research Paper

Critical factors determining public transport access level in Abuja federal capital territory of Nigeria

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This study aims to investigate the key factors which determine access to public transport service in Abuja, the Federal Capital Territory (FCT) of Nigeria. Data were collected based on ten public transport access levels indicators namely: Safety, transport fare, bus availability, comfort level, speed on transit, delays at parks, bus stops and on transit highway, adherence to estimated arrival time, adherence to estimated departure time, reliability of bus schedules and bus overloading. Data on these factors were collected from administration of questionnaires to 859 public transport commuters in 17 major road transport terminals across the FCT. The data were analysed using the factor analysis, correlation, and regression method. The result shows that three factors namely, adherence to estimated departure time, fare charged by the operators, and reliability of bus schedules on routes together explained about 54% of the cumulative total variance, leaving the remaining 46% to seven other factors and residuals. The Spearman's rank correlation matrix for all the variables indicates that they were all positively correlated at various degrees. The standardized co-efficient of the regression analysis revealed that, bus service reliability is the major determinant of public transport access level in the study area. In order to raise the current access level of commuters to public transport in FCT, operators must improve on the level of service in line with the three critical factors which the study has identified*.

Key words: Factors, determination, public, transport, and accessibility.

INTRODUCTION

Accessibility according to Richardson and Young (1981) can be defined as the ease of getting to a place and as "nearness to place or nearness to activities", as such it can be measured in relation to distance-socially, economically, and physically.

Martinez (2000) and Wegener (1996) considered accessibility as one of the important factor in shaping land use patterns, this is because, individual will base their decisions of where to reside (or where to locate their businesses) on the ease of accessing the services they desire; therefore, making it an important consideration in the planning and development of policies associated with transport, and in determining land use configurations within urban space.

Within the framework of transportation planning, Niemeir (1997) noted that accessibility can be defined as the ease

with which desired destinations can be reached. Although the nexus between accessibility and transportation planning is well acknowledged in literature, a major problem usually encountered in quantitative study of commuters' access to public transport is that of deciding what constitute factors and the yardstick to determine the level of accessibility. However, Ahmed (2005), Abumere (1993) and Sumaila (1989) opined that accessibility should be defined in broad sense which include indicators that measure the physical, economic, social and other aspects.

Mfinanga and Ocheng (2006) defined public transport access level as the overall measured or perceived performance of the public transport system from the viewpoint of the commuters, this can be used to denote the ease of getting to and quality of service derived from the operational characteristics of transportation facilities. This reflects the degree to which transit service is available to a given location and the comfort and convenience of the service provided to commuters (Papacostas and Prevedouros (2008), Qualtro (2004) highlighted the indices of an accessible public transport system to include:

1. Safety
2. Reliability
3. Comfort
4. Availability
5. Public transport fare
6. Distance to access points and convenience.

The road-based transportation which is dominant mode of urban commuting in Nigeria is continuously deteriorating, the quantity and quality of all related service and infrastructures have been on the decline and the cost of vehicle maintenance is increasing (Ashiodu (2011), Amiegbebhor (2009) Oyesiku, 2002). Pederson (1980) asserts that cities are creatures of transport system, and Ogunsanya (2002) observed that transport is the "maker and breaker of cities", as the same transport that makes a city could also destroy and stagnate it if it is not effectively planned and managed.

The spatial location of life enhancing activities in urban centers brought about the increasing need for people to travel to work, school, and shopping centers in order to satisfy their daily needs. Overcoming the distance separating them from their activities requires a means of movement, and the majority without personal vehicles must make use of public transport for such journey (Oluwole and Ojekunle, 2016).

This study investigates the critical factors among many others which largely influence commuters' access to public transport service in the Abuja, FCT-Nigeria.

LITERATURE REVIEW

Fundamentally, urban transportation seeks to link residents and employment as well as producer and users of goods and services. The demand for public transport in most Nigerian cities is projected to be on the increase because large proportions of urban residents are low-income earners who cannot afford personal vehicles.

Mabogunje (2008) pointed out that the estimate of transport demands in metropolitan Lagos in the 1990 range from 7 to 10 million passenger trips daily out of which over 95% are undertaken by road, primarily by car bus and taxi. The current available means of public transport are very few and limited especially when compared with what is obtains in developed countries of Europe and America where trains are used for intra and inter urban movement (Sumaila, 2004).

Adasanya (2011) observed that cities across the world are in a state of rapid transition, the inability and sustainability of these cities are intrinsically interwoven with not only the degree of efficiency and effectiveness with which existing transport capacity is managed but also how well intermediate and future transportation plans and programmes are articulated, laid out, and implemented in order to meet the needs of the people. The spatial structure of cities especially in developing countries is highly varied and complex, some areas are adequately provided with services and facilities while in other area is grossly inadequate (Oluwole 2016 and Ogwude (2011). The variation in the spatial structure results in different socio-economic characteristics of urban dwellers with strong challenges of getting equal and efficient urban service for the disadvantaged. The quality of life in most cities is poor and closely related to accessibility to alternative employment, education and medical facilities, essential public services and nature of recreational open spaces (Vasconcellos 2011). A comparison of government and private operation of public transport operations in Nigeria shows that the state and local government public transport are more organized while private sector operators are largely unorganized.

Government-owned public transport have better trained staff and maintenance facilities than most of the private sector operators; their service are often provided on fixed routes and are relatively cheaper than those provided by private sector operators. Government owned public transport operator also have service schedules, but in practice are rarely followed because of the inadequacies of vehicle, declining fleet utilization rates, growing competition with private and para-transit operators, poor traffic management, congestion especially during peak travel periods and other problems associated with the operating environment (Umar, 2003).

In a study of public transport in Nigeria, the World Bank (1990) and Adetunji (2000) reported that taxis and private vehicles carrying fare paying passengers represent 53% of the public transport trips, while 30% made use of motorcycles. In many cities in developing countries, motorcycles account for about 90% of feeders' trips to taxis and mini bus terminals.

Similarly, in a study of the supply of transport infrastructures in Lagos metropolis, Ogunsanya et al.

(2004) noted that most urban road networks are not only poorly developed with feeder streets, they are grossly inadequate and their inadequacies more often than not forced vehicles to concentrate on the primary roads with serious implications on commuters modal choice and mobility pattern especially along the same urban transport corridors, a situation which has compounded public transport accessibility problems in the environment. The Ogunsanya and Galtima (1993), World Bank (1997) and Adesanya et al. (2002) affirmed that urban parts in Nigeria pay very high proportion of their income for transport services and spend long period of time trekking, travelling, and waiting for infrequent and unreliable bus service. Ndikom (2008) identifies the poor state of Nigerian roads as one of such problems. He further noted that both the rural and regional roads in Nigeria are in high degree of deterioration, the result of which is poor public transport service quality.

The public transport system in Abuja FCT which caters for about 1.4 million commuters (Oniyangi, 2012) is today faced with numerous challenges, the complex and heterogeneous traffic pool, largely dominated by private vehicles and poor service level of the public transport operator creates unbearable waiting time and traffic congestion.

The centralization of government functions, commercial activities and key private sector organizations in the city center, leaving majority of the populace at the surrounding towns and settlements leads to large volume of vehicular movement to and from the city, and the adjoining satellite settlements every day. The emerging features of this commuting challenge is poor access to public transport and this need to be thoroughly studied, because it will not only help in mitigating the commuting challenges, but also form a reliable and objective information source for the transportation operation plans for the territory which the FCT Transport Policy admitted will be dynamic and could be subject to change as the city grows and as the commuting pattern is formed over time (Oluwole, 2014). It is in the light of the foregoing that this study investigates commuters' access to public transport service in the Abuja the federal Capital territory (FCT) of Nigeria.

METHODOLOGY

The data types collected were factors influencing commuters access level to public transport, frequency of commuter's trip using public transport, level of public transport usage by commuters who own car, distance from commuters residences/offices/activities centers (Point of Interest (PoI's) to public transport bus stops, terminals, and average walking time to bus stops/terminals (Service Access Points (SAP's)) from commuters' trip origin and destination.

Others are duration of time commuters wait at the bus stop, transit highway and terminals before boarding the bus and variation in commuters waiting time at the different traffic conditions, monetary costs of transport along a route under different traffic condition (peak and off-peak), commuters' responses to different public transport fare regime among others. These data were

sourced from FCT bus commuters.

Five of the six FCT Area Councils were purposively selected, because they accounted for almost 96% of FCT's population. These Area Councils were the closest to the city centre where majority of the intra commuters reside. The Area Councils were: Abuja Municipal Area Council (AMAC), Bwari, Gwagwalada, Kwali and Kuje. In each of the five area councils, all the major settlements and terminals which serve as commuters' traffic concentration points for smaller settlements around them were covered during questionnaire survey. Considering the target populations which are commuters, it is believed that the best form of contact with them will be at their respective terminals and bus stops.

To this end, fourteen terminals which were operated by private concerns and three government-owned were chosen. Deriving from the pilot survey, a total of 16,563 commuters were estimated under the privately operated public transport, while 740 commuters were estimated under the government operated public transport. Therefore, a total of 872 commuters representing 5% and private operators and 315 representing 30% of government operators were adopted for survey as the sample size.

Borg and Gall (1971) suggested a minimum of 5% sample size as being adequate for population above 10,000 and minimum of 10% for population below 5000, especially where the population of studies is homogenous as it is the case with the current study. Furthermore, the need to reduce the likelihood of double sampling, bearing in mind that commuters can make multiple trips between and along a route within and between days of the months which the survey lasted.

The survey was conducted over different time scales, morning, afternoon and evening period of the weekdays (Monday-Sunday) and over different traffic and weather conditions between June and August 2016 so as to capture the various dimensions that the different conditions may introduce into the public transport fare, time, and the general access level in the FCT.

Different sampling technique were used in order to reach the target respondents, first the purposive sampling method was adopted to choose five Area Councils out of the existing six, while the stratified sampling methods was used in the selection of buses, based on two classes of private and government operators. This is hinged on the preliminary understanding that there are different public transport operators and vehicle types (small, medium and large), which the commuters used and must all be captured. The systematic random technique (1 out of 5) was then used in the identification of the specific vehicle types and commuters to be surveyed. This is because there is no sampling frame from which random numbers can be generated for the purpose of adopting a simple random scheme.

Since vehicles and commuters are always mobile, the point of interaction with them is the motor parks or bus stops. This is because the waiting time during the period of boarding and disembarking by commuters provide the allowance for the elicitation of the information required with the aid of field assistants that were well trained. Figure 1 shows the study area.

Selection of variables (Factors)

The access level determinants were based on ten widely reported public transport access level measurement items (Ali, 2011; Basorun and Rotowa, 2012) as contained in Table 1. Thus, ten variables were selected for investigation, namely: safety level of the vehicle; fare changed by the operators; real time availability of the vehicle; vehicle comfort level; public transport speed on transit; delays at parks, bus stops, and on transit highway; adherence to estimated arrival time; adherence to estimated departure time; reliability of bus schedules on routes; and level of overloading practices.

Kaiser–Meyer–Olkin criterion (KMO) and Bartlett's test of
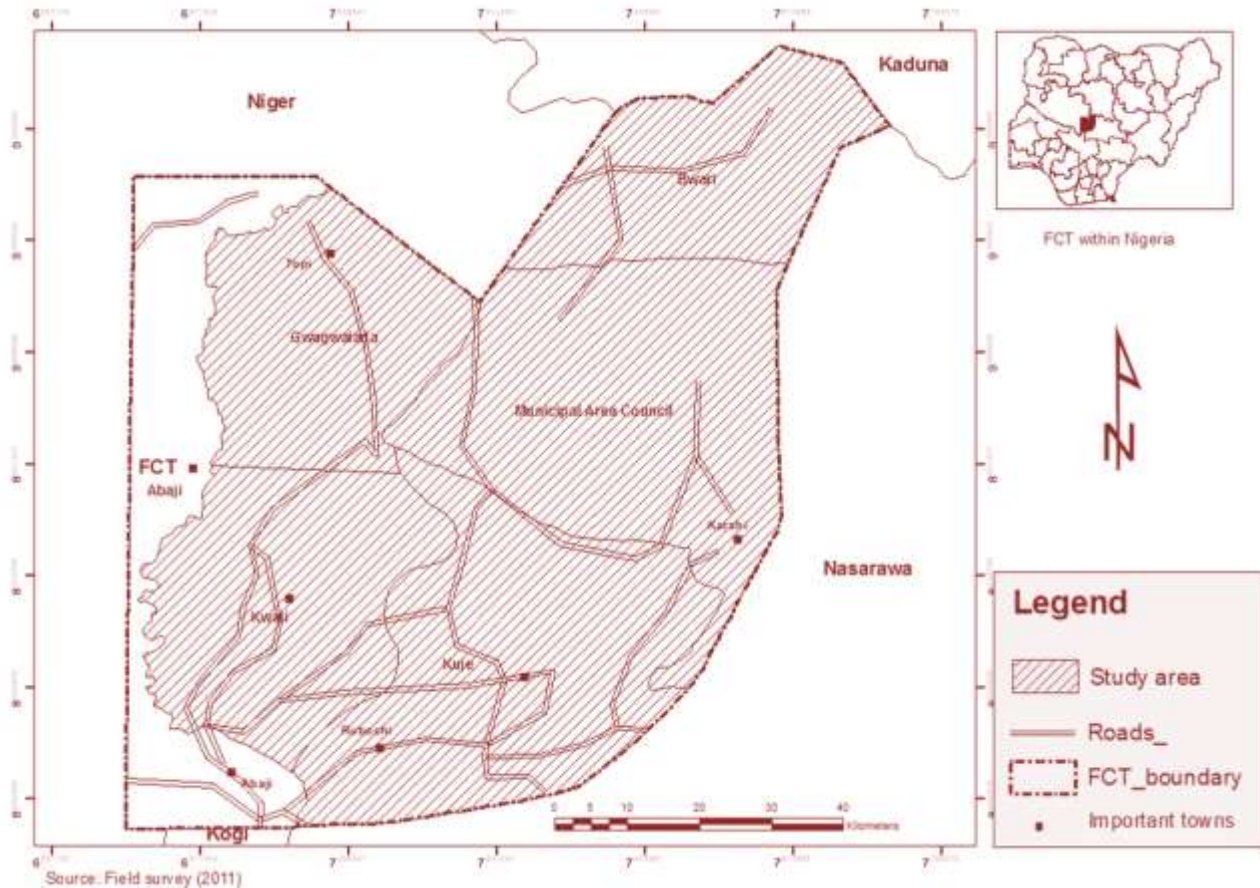
Figure 1. The study area.

Table 1. Factors influencing public transport access level.

S/N	Variable	Label
1	Safety level of the vehicle	x_1
2	Fare changed by the operators	x_2
3	Real time availability of the vehicle	x_3
4	Vehicle comfort level	x_4
5	Public Transport Speed on transit	x_5
6	Delays at parks, bus stops and on transit highway	x_6
7	Adherence to estimated arrival time	x_7
8	Adherence to estimated departure time	x_8
9	Reliability of bus schedules on routes	x_9
10	Level of overloading practices	x_{10}

Source: Researcher's compilation (2016).

measure of sampling adequacy was used to evaluate the reliability of the instrument internal consistency, the KMO and Bestlett's test according to Landau and Everitt (2004), is the average of all possible split - half coefficient resulting from different ways of splitting the scale items.

A value of 0.7 or below indicates unsatisfactory consistency and reliability, any value above 0.7 indicates satisfactory reliability and it is significant enough for the variables to be correlated. The result as indicated in Table 2 shows that the internal consistency of each measure is 0.889 which implies a good level of reliability. Furthermore, factor analysis was used to derive the set of variables in terms of smaller (critical) number of dimensions out of the total number of variables in the analysis. Essentially, it assesses whether the co variances between the set of variables can be explained

Table 2. Reliability (KMO and Bartletts) test statistics.

Kaiser-Meyer-Olkin measure of sampling adequacy		0.889
	Approx. Chi-square	3366.277
Bartlett's test of Sphericity	Df	45
	Sig.	0.000

Source: Authors computation (2016).

Table 3. Communalities of the factors influencing the use of public transport.

S/N	Factors	Initial	Extraction
1	Safety level of the bus	0.246	0.403
2	Fare changed by the operators	0.453	0.616
3	Real time availability of the bus	0.440	0.563
4	Bus comfort level	0.471	0.558
5	Speed	0.447	0.524
6	Delays at parks, bus stops and on transit	0.404	0.472
7	Adherence to estimate arrival time	0.515	0.574
8	Adherence to estimate departure time	0.669	0.690
9	Reliability of bus schedules on routes	0.484	0.604
10	Level of overloading practices	0.319	0.360

Extracted method principal axis factoring. (Source: Authors computation (2016).

in terms of smaller (critical) common factors otherwise called latent variable. The factor analysis model expresses each variable as a linear combination of underlying common factors $f1, f2, . . . , fm$, with an accompanying error term to account for that part of the variable that is unique (not in common with the other variables).

For $y1, y2, . . . ,yp$ in any observation vector **y**, the model is as follows:

$$y1 = \lambda11\ f1 + \lambda12\ f2 +\cdot\cdot\cdot+\lambda1m\ fm+\mu1+\varepsilon1 \tag{1}$$

$$y2 = \lambda21\ f1 + \lambda22\ f2 +\cdot\cdot\cdot+\lambda2m\ fm+\mu2+\varepsilon2 \tag{2}$$

$$...yp= \lambda p1\ f1 + \lambda p2\ f2 +\cdot\cdot\cdot+\lambda pmfm+\mu p+\varepsilon p \tag{3}$$

The f's is the random variables that engender the y's. The coefficients $\lambda i\ j$ are called *loadings* and serve as weights, showing how each individually depends on the f's. With appropriate assumptions, $\lambda i\ j$ indicates the importance of the jth factor $f\ j$ to the ith variable yi, and can be used in interpretation of $f\ j$.

The variables $y1, y2, . . . ,yp$ *are represented* as linear combinations of a few random variables $f1, f2, . . . , fm\ (m < p)$ called *factors,* with mean vector μ_i. The factors are underlying *constructs* or *latent* variables that "generate" the y's. The F_1 and $F_2.....F_k$ are the common factor in each variable Y. While $\lambda1, \lambda2$ signify *loading* and serve as weights, which shows how y_i depends on the common factors F_i. It is therefore open to question. If the original variables $y1, y2, . . . ,yp$ are at least moderately correlated, the basic dimensionality of the system is less than p.

The Spearman's correlation matrix was used to investigate the types and strength of association between the pairs of variables in table 6 that influence commuters' access to public transport services in FCT. The regression analysis was used to build a model that will explain the contribution of each of the accessibility factors

to commuters' level of access to public transport service in Abuja FCT Nigeria.

It was conceptualized that, there is as set of variables $X_1, X_2, X_3.......X_n$, which can be used to explain public transport access level in the FCT. This may be mathematically stated as:

$$y= f(X_1, X_2, X_3...............X_n) \tag{4}$$

And can be operationalized using the multiple regression equation thus:

$$y= a+b1X_1+b_2X_2+b_3X_3.........bnXn + e \tag{5}$$

Where:

y= the dependent variable i.e. access to public transport;
a= Constant;
$b_1, b_2, b_3..............b_n$= the coefficient of independent variables;

$X_1, X_2, X_3........X_n$ are the independent variables, that is, distance from bus stops/terminals to commuters' trip origin and destination, public transport fare, bus service comfort, safety, speed in transit, adherence to estimated arrival time etc.
e = random error term (measuring the unexplained variable).

RESULTS AND DISCUSSION

The result of the analysis as presented in Table 3 shows that the estimates of the communality before and after the extraction of the variable reveals that not much of the variance of the variable items safety (40%), delays in terminals/bus stops and in-transit (47.2%) and overloading

Table 4. Total variance of the factors that determines public transport access level.

Factors	Total	Initial Eigen values		Extracted sums of square loadings		
		% of variance	Cumulative %	Total	% of variance	Cumulative %
1	4.410	44.101	44.101	3.967	39.669	39.669
2	1.676	16.755	60.856	1.208	12.078	51.746
3	0.714	7.136	67.994	0.188	1.881	53.628
4	0.604	6.046	74.034	-	-	-
5	0.545	5.454	79.487	-	-	-
6	0.469	4.687	84.174	-	-	-
7	0.443	4.429	88.603	-	-	-
8	0.412	4.116	92.719	-	-	-
9	0.407	40.69	96.788	-	-	-
10	0.321	3.212	100.00	-	-	-

Extracted method: Principal Axis Factoring (Source: Author's computation (2016).

of buses (36%) can be attributed to the three common factors in the communalities table.

However, variables like adherence to estimated departure time, fare charged by the operators and reliability of bus schedules on routes, showed a variance of 69, 61.6 and 60.4%, respectively. This high percentage variance suggests that the variable can be attributed to the three common factors.

In addition, the variances of the extracted factors (Table 4) shows that the percentage of the total variance accounted for two factors with Eigen values greater than 1. The total variance explained indicates that factor one with an Eigen value of 4.410 accounts for 44.10% of the total variance explained by the analysis.

Similarly, factor two with an Eigen value of 1.676 accounts for 16.76%. The factor loadings provide a clear indication of the underlining level of the quality of the services of public transport that influence its accessibility. The importance of the loadings is that it has reduced the most influencing factors to two major factors with Eigen value greater than 1:00. These are the dominant loadings for each factor. These Eigen values are the proportion of the total variation in the data set that is explained by a factor.

As observed in Table 4, two factors accounted for about 52% of the explanations that is, determining commuters access to public transport service in Abuja the FCT. Interestingly, the third factor accounts for very small proportion of the total variation of the explained variables (about 1.9%). The scree plot in Figure 2 shows the pattern in which this unexplained variation is distributed among the variables. This plot demonstrates the distribution of the variance among the factors graphically. The 'elbow' shape of the curve indicates that higher order factors contribute to a decreasing amount of additional variance with a marked decrease in the second (fare charged by public transport operators) and third factor (real time availability of the bus). This implies that

access to public transport can be greatly influenced by the first two factors.

Since the communality table alone cannot be relied upon to identify the factors which determines commuters' access to public transport service (Landau and Everih, 2004), the factor rotation (varimax) was further employed. The objective is to maximize the variance of the square loadings to produce orthogonal factor that will be used to interpret the factor analysis. To this end, an arbitrary threshold value of 0.4 is equated as high loadings. Furthermore, variables that load on factors 1 and 2 are considered important explanatory variables.

Table 5 shows the rotated factor matrix, a careful examination of the table indicate that all the variable load on at least one factor. Variable 4 (comfort of the bus) load on factor 1, 2 and 3, while variable 5 (the bus speed) load on factor 1 and 3. However, Bus departure (number 8 in Table 5) time appears to be the most important factors which determine commuters' access to public transport as it loads the highest value (0.812) on factor 1. This is followed by the Ninth variable (bus service reliability) which loads 0.769 on factor 1, while the seventh factor arrival time load *700 on factor 1. Notwithstanding, factor 4 (bus comfort) and 5 (bus speed) are also very important determinant factors as they load on more than 2 factors.

All these important factors, (departure time, bus service reliability, arrival time and speed) can be summed - up in one phrase: *fast access and short transit time*. This implies that commuters will be attracted and patronize public transport service if the time spent at bus stop, terminals or transit highway before getting bus to commence the trip as well as the time spent before reaching the destination is short.

The implication of these can be explained against the background of the fact that, the FCT is predominantly an administrative territory with high concentration of economic and administrative activities at the city center, while majority of the workers (commuters) reside at the

Scree plot
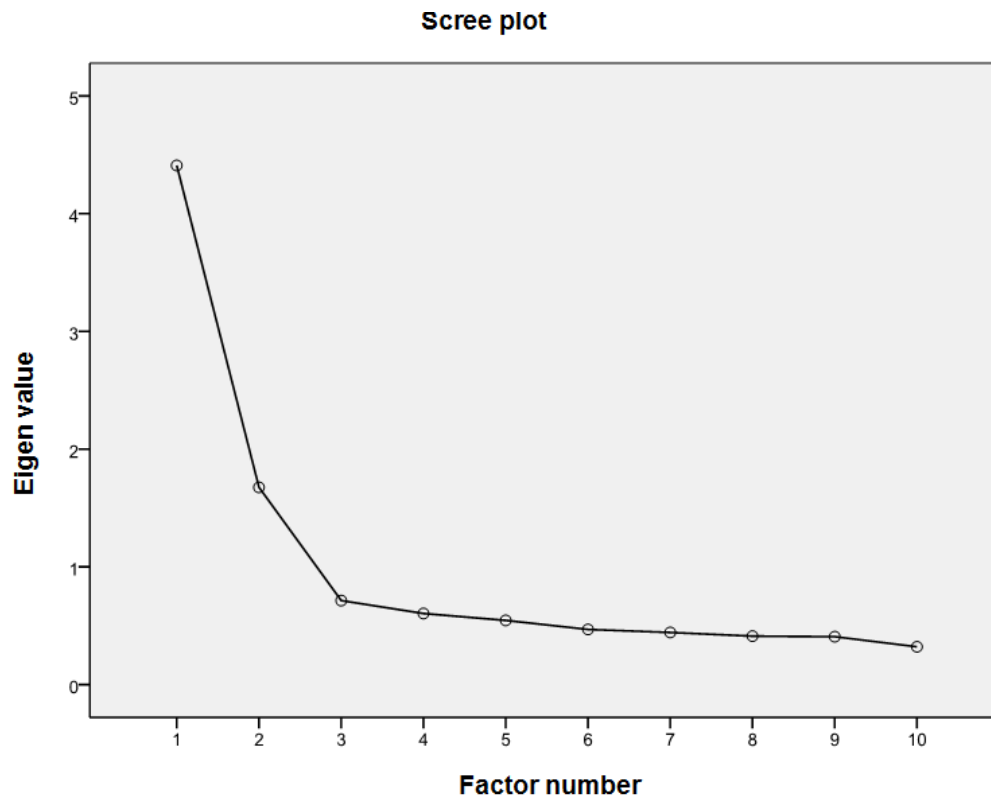
Figure 2. Distribution of the factor loading.

Table 5. Rotated factor matrix of the public transport access level variables.

Bus service level element	Factor		
	1	2	3
Bus safety level	-	0.631	-
Fare charged	-	0.710	-
Availability of Bus	-	0.688	-
Bus comfort level	0.429	0.446	0.418
Bus speed	0.520	-	0.409
Minimum delays	0.509	-	-
Adherence to estimated arrival time	0.700	-	-
Adherence to estimated departure time	0.812	-	-
Reliability of Bus	0.769	-	-
Bus overloading practice	0.589	-	-

Extracted Method: Principal Axis Factoring; Rotation Method: Varimax with Kaiser Normalization. (Source: Author's computation (2016).

periphery, having to commute daily over a working hours that is less flexible (as all work places, schools, etc.) which open between 7 to 9am and close between 2 to 5pm. It is expected that there will be serious rush to catch - up any available public transport vehicle at that hour where most often, the supply capacity of the public transport service is very limited.

During this time, commuters will be less mindful of the fare charged and safety level of the bus, all in a bid to just reach their activity places. It is therefore not surprising that strict adherence to departure time of bus (0.812), reliability of bus service (0.769), and the adherence to estimated arrival time at the point of destination (0.700) stand out as the most important factors that FCT bus commuters consider as determining their patronage of public transport. This finding is similar to the outcome

Table 6. Correlation matrix of the public transport access level factors.

Variable	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
X_1	-	-	-	-	-	-	-	-	-	-
X_2	0.436	-	-	-	-	-	-	-	-	-
X_3	0.420	0.573	-	-	-	-	-	-	-	-
X_4	0.251	0.496	0.492	-	-	-	-	-	-	-
X_5	0.147	0.395	0.412	0.534	-	-	-	-	-	-
X_6	0.132	0.371	0.344	0.488	0.478	-	-	-	-	-
X_7	0.065	0.257	0.291	0.451	0.509	0.510	-	-	-	-
X_8	0.061	0.232	0.301	0.446	0.498	0.479	0.650	-	-	-
X_9	0.056	0.179	0.239	0.407	0.457	0.423	0.555	0.635	-	-
X_{10}	0.021	0.115	0.130	0.319	0.367	0.377	0.404	0.484	0.486	-

Source: Author's computation (2016).

ofthe UK Department of Transport (2003) study, which identifies high frequency of services that are reliable as important needs of the UK public transport users. Conversely, Mistral and Nandagopal (1993) and Naniopoulos (1999) identify in India that public transport service elements are by nature not independent of one another, but to some extent depend on the degree of ratings which commuters attach to them, this justifies the need to determine the degree of the relationships between the ten variables as presented in Table 6. The factors are denoted as:

X_1 – Bus safety level
X_2 – Fare changed
X_3 – Availability of Bus
X_4 – Bus comfort level
X_5 – Bus speed
X_6 – Minimum delays
X_7 – Adherence to estimated arrival time
X_8 – Adherence to estimated departure
X_9 – Reliability of Bus
X_{10} – Bus overloading practices

The results, as presented, show that the associations of the variables are all positively correlated. It is instructive to note that the strongest positive correlation between the pairs of variable is between availability of bus and public transport fare along the route, (r= 0.573, P<0.001).

The implication of this is that the more available the public transport bus in real time and commuters are seeing it to be meeting their daily commuting needs, the more they feel less bothered with the fare charged by the operator. Since the commuters are getting value for their money, they tend to be less sensitive to how high or low the fare charged for the use of such public transport.

Similarly, the correlation between bus speed and comfort level shows partial positive correlation (r= 0.534, P < 0.001). This means that, the faster the bus in transit, the more likely, they will consider the trip comfortable and will be disposed to the use of public transport. This again

is expected; because a rationale commuter will want to maximize his /her time while making his/her trip.

Furthermore, the association between adherence to estimated arrival time and minimum delays (r= 0.510, P < 0.001), is also strong. This suggests that the trip transit time will be short and the estimated arrival time to the destination by the bus will be achieved. It is fundamental to understand that this correlation provides integrity checks on the commuters' responses on the variables under investigation.

Result of regression analysis

The overall access level to public transport service in the FCT (dependent variable) was determined using a regression model which incorporate: bus safety level, fare charged, availability, adherence to departure time, bus service reliability, estimated arrival time, bus comfort, delays in transit and bus overloading to come out with a model which explains access level to public transport services in the FCT (Table 7). Therefore, the overall commuters' access to public transport service is described thus:

Commuters' level of access to PT= 1.41 (constant)+-0.003 (safety)+-0.088 (Fare charged) +0.094 (Availability)+0.038 (Comfort) +0.100(Speed) in transit)+0.001(Delays) +-0.074(adherence to estimated arrival time)+-0.050 (Adherence to estimated departure time) +0.470 (bus service reliability)+0.182 (bus overloading)

The interpretation of the aforementioned equation as observed from the regression slope is that overall commuters' level of access to public transport will increase as these ten (10) factors get better. The standardized regression coefficient beta (β) values indicate bus service reliability has the greatest impact (β =.470 p=.000) on commuters' overall access level. This is

Table 7. The regression model.

Independent variable	Unstandardized coefficients		Standardized coefficients	t	Sig.(p)
	B	Std. Error	Beta		
(Constant)	1.407	0.411	-	3.424	0.001
Safety	-0.003	0.071	-0.003	-0.041	0.968
Fare charged	-0.84	0.073	-0.088	-1.156	0.249
Availability	0.093	0.076	0.094	1.219	0.224
Comfort	0.031	0.059	0.038	0.522	0.602
Speed	0.093	0.065	0.100	1.427	0.155
Delays	0.001	0.085	0.001	0.007	0.994
Arrival time	-0.071	0.076	-0.074	-0.926	0.355
Departure time	-0.049	0.086	-0.050	-0.574	0.567
Reliability	0.461	0.070	0.470	6.557	0.000
Overloading	0.182	0.072	0.182	2.523	0.012

R^2= 0.375, Adjusted R^2= 0.345   P ⊂001; *Dependent variable: Commuters' access to public transport service (Source: Author's computation (2016)).

followed by absence of overloading in bus (β= .182,p .012), bus speed in transit $(\beta = .100, p .156)$ and bus availability (β = .094,p .224) in that order of magnitude.

The R^2 which is the percentage of the variance in y (dependent variable) that can be predictable from x (independent variables) is 0.375 or 38%. Keren (2013) observed that there are two reasons why it might just be fine to have low R^2 value.

Firstly, investigation which attempt to predict human behavior regarding certain issue- such as this study has done, typically has R^2 lower than 50%, this is because humans are just harder to predict than any physical process. Secondly, if R^2 is low but predictors are statistically significant, important conclusion about how changes in the predictor values are associated with changes in the response values can still be drawn. This is because regardless of the R^2, the significant co-efficient still represent the mean change in the response for one unit of change in the predictor, while holding other predictors in the model constant. Furthermore, noting the closeness between the R^2 value (.375) and the Adjusted R^2 value of 0.346 in Table 7 it can be concluded that the data is fit for the model.

These four factors (bus service reliability, absence of overloading in bus, speed of bus in transit and real time availability of bus) therefore, can be said to be very important and critical in determining the level of commuter access to public transport service in FCT. The reliability of bus service along the routes, devoid of breakdowns and delays on the road, combine with the real-time availability in the bus stop and terminals when the commuters intends to make their trip will determined the continuous patronage of the public transport by the car-owned and non-car groups of commuters.

The result therefore indicates that if public transport service can be made more reliable, available and speed in transit enhanced, therefore, commuters' access level

to public transport service in FCT can be boosted. The principle of real-time availability of public transport vehicles when needed is very important, because commuters trip are mostly work, school, office or business appointment related, whose time are fixed. The demand for public transport at this time is usually high. This time also coincides with the popular *peak or rush hours* in the FCT, and it occur in the early morning between 7:00 to 9:00am, and early evening hours between 3:00 to 5:00pm during the working days (Monday to Friday).

The service comfort of FCT public transport at the time of field investigation was relatively poor; this has been a disincentive for commuters who have private car. For example, the basic requirements like comfortable seats, open window for air flow, bus floor height among others do not measure up to standard. Majority of the vehicles are minibuses which do not provide adequate leg room or adequate ceiling height for standing.

The situations can be critical during rush hours when commuters' will have to stand for a long time, in a crowded bus and on a congested road. Though the issue of comfort at the time of this survey does not influence access level as it might be expected, it is important that consideration should be given to it in the public transport improvement effort. This is because most commuters on provided cars which this study could not elicit data from are likely to be attracted to public transport patronage if the current level of comfort is improved upon.

CONCLUSION

This study has established, with respect to FCT Abuja-Nigeria, the four major factors influencing commuters' usage of public transport and by implication commuters' adoption of it. Therefore, basic standards should be set with regard to these parameters and compliance should

be strictly monitored by the law enforcement agents that is, directorate of road traffic service (DRTS), federal road safety commission (FRSC) and FCT Transport Secretariat. The study has also identified some key factors such as walking distance to bus stops/terminals, public transport fare, reliability, comfort, adherence to estimated departure and arrival time as very crucial in raising commuters' access to public transport in the FCT.

Therefore, constant improvement of the service level of these factors should constitute part of the public transportation planning and administration agenda of the Federal Capital Territory hence forth. The implementation of these recommendations is important because transport as a derived demand can affect the quality of life and the general productivity and development of the territory.

RECOMMENDATION

In view of the forgoing result and discussions, the following recommendations are offered towards enhancing better public transport service that will be accessible to the commuters in Abuja FCT in particular and in general, other places with similar public transport access challenges in Nigeria:

1. There should be collaboration by the private sector organizations and FCT administration towards providing a safer public transport buses for commuters, with a view to increasing the general access level.
2. Affordable public transport should be provided to link residential areas and work places in line with the criteria setup by the FCT master plan and land transport policy. This will eliminate frequent need for intermediate transport, and the associated costs or walking distance to the existing public transport bus terminals/stops in the FCT;
3. There should be a periodic public transport driver and operators' training/ sensitization to be jointly carried out by FCTA, DRTS, FRSC and transport operators unions, in order to initiate and sustain good attitudinal modifications amongst public transport operators. Such training/sensitization should include but not limited to defensive driving, road traffic rules and regulation, accident causes and prevention methods, the right of other road users, quality service management among others;
3. There should be a dedicated public transport lane in all the routes which will separate public transport vehicles from other vehicular traffic, this will not only increase bus frequency, it will reduce transport fare and transit time and also, in a way, discourage private car usage for commuting within the FCT. The FCT Transport Secretariat, Ministry of Federal Capital Territory, Federal Ministries of Power, Works and Housing should conscientiously strive to make public transport attractive;
4. The accessibility and patronage of public transport

depends largely on commuters' perception of their service quality, closeness of terminals to their trip origin/destination, cheap fare, and comfortable interior and safe operation as all things being equal; they are likely to attract commuters than other means of transport. Therefore, the policy goal, objectives, and strategies should be formulated and implemented on each of the factors.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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Full Length Research Paper

Re-analysis of tropical cyclone variability from February 1956 to February 2016 over the western North Pacific using the TianGan-DiZhi calendar

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Properly organized data is vital for appropriate statistics and theories. In this study, it was hypothesized that raw tropical cyclone (TC) data labeled with the current Gregorian time system, dampened the dominant signals and order in the data. Therefore, the objective of this study was to explore and reorganize the data, using the TianGan-DiZhi (T-D) calendar. All 6 h TC records in 60 sidereal years over the western North Pacific (WNP) were investigated after the data were transferred from the Gregorian to T-D calendar. TianGan and DiZhi, two collections of elements in the T-D calendar, were then quantified to conduct correlation analyses with different TC parameters. The results showed significant temporal and spatial correlation between 6 h TC records and variables in the T-D calendar over different timescales. Temporally, 6 h TC records in the T-D summer, generally from May 5 to August 6, of the 60 sidereal years were significantly correlated with the strength difference between yearly TianGan and yearly DiZhi for the sidereal years. Spatially, the longitudes and latitudes of 6 h TC records were also significantly correlated with daily variables in the T-D calendar. We conclude that, TC data over the WNP can be better interpreted using the quantified T-D calendar than the Gregorian calendar. Since this ancient time-labeling tool can provide properly organized data, it might be used to modify some inputs in current numerical models to improve forecasting power.

Key words: Tropical cyclone, frequency, temporal, sidereal, Gan-Zhi, calendar.

INTRODUCTION

In general, the variations in tropical cycle (TC) frequency worldwide are related to various factors (Landsea, 2000), including the El Nino-Southern Oscillation (ENSO), Quasi-biennial Oscillation (QBO), and Madden-Julian Oscillation (MJO).

However, recent studies have found a link between solar activity and TC frequency (Elsner and Jagger, 2008;

Hodges et al., 2014). Similarly, the number of sunspots are significantly correlated with hurricane frequency on a 22 year cycle (Mendoza and Pazos, 2009; Pazos et al., 2015).

These results indicating a solar influence on TCs naturally suggest the Chinese T-D calendar: the TianGan cycle is 10 sidereal years and DiZhi cycle is 12 sidereal

years. This means the average value of both, 11 sidereal years, is very close to the solar or sunspot cycle period, which is nearly 11 years according to the Wikipedia. This calendar was widely used historically, and is still used in traditional Chinese medical researches (Tang et al., 2016) and in some climate researches (Tang et al., 2015). Though, there is still no clear and well-distinguished pattern identified for TC variability (Camargo et al., 2010). The current lack of consensus and lack of forecasting naturally lead to the question: Where is the problem?

Could problems exist in current theories? Maybe, but all theories have more or less supporting evidence. Therefore, could the problem lie in the raw data? On initial inspection this appears unlikely, yet suspected raw data labeling cannot be excluded after serious consideration. When the raw data is recorded, the organization method may have influenced and even distorted the data characteristics. This is a possibility, generally ignored yet potentially exciting if true. As a result of such a possibility, it was hypothesized that the current Gregorian time system, in which the raw TC data was organized, dampened some data characteristics. This study explores reorganizing and reanalyzing the data using the T-D calendar.

MATERIALS AND METHODS

Data

About one-third of TCs worldwide and related researches ensued in the western north-Pacific (WNP) (Chen et al., 1998; Chan JCL, 2000; Chen et al., 2006; Yuan et al., 2009); therefore, this basin was chosen for investigating the relationship with the T-D calendar. TC data, the CMA-STI Best Track Dataset for Tropical Cyclones over the western North Pacific, was obtained from www.typhoon.gov.cn. A total of 2008 TCs covering the period from 5 February, 1956 to 3 February, 2016, 60 sidereal years in total, were used in this study. From all 6 h records, 48134 records with intensities labeled "1", Tropical Depression, to "6", Super Typhoon, were used. Records with intensities labeled as "0", weaker than Tropical Depression or unknown intensity, or "9", Extratropical Cyclone stage, were not used.

T-D calendar and its quantification

The TianGan-DiZhi can be separated into TianGan and DiZhi, which are literally translated as heavenly stems and earthly branches, respectively. They can also be abbreviated as Gan-Zhi using the second Chinese character for each phrase.

In the T-D calendar, time is defined in a way quite different from in the Gregorian calendar (for details: https://en.wikipedia.org/wiki/Sexagenary_cycle). TianGan has 10 components or parts, they are referred as T1 to T10, where T stands for TianGan, and the number indicates the order. DiZhi has 12 components or parts, referred to as D1 to D12. One component of TianGan and another component of DiZhi were used in pairs to label time on different time scales; the names of all components of TianGan and DiZhi are presented in Figure 1.

Hours, days, months, seasons, and years are defined differently on the T-D calendar as T-D hours, T-D days and T-D months. For example, the first T-D month, or Zi Yue, generally begins on 7

December. T-D summer is defined as the three T-D months of Si, Wu, and Wei, and generally ranges from 5 May to 6 August. T-D years or sidereal years are generally from 4 February of a year to 3 February of the next year.

Because 60 is a least common multiple (LCM) for TianGan, which has a cycle of 10 time points, and DiZhi, which has a cycle of 12 time points, the 60 different pairs of TianGan and DiZhi constitute a basic cycle, or sexagenary circle. As a result, TianGan and DiZhi cycle over 60 T-D h or 5 T-D days, 60 T-D days or 2 T-D months, and 60 T-D years. Time points in a basic time sequence cycle are heterogeneous, while time points with a gap of 60 are homogeneous.

TianGan and DiZhi have been generally viewed as category notations to record time, and all the previous studies using them followed this tradition. However, this construct does not present the whole story. Different components of TianGan and DiZhi were possibly also related to different strengths of Yang and Yin. Generally, Yang is related to warm and hot climate or conditions, and Yin is related to chilly and cold climate or conditions. Yang and Yin describe the process from birth, growth, prime, and decay to death for everything in the universe (Lu, 2013).

As a result, the T-D calendar can be quantified in the following steps. First, as both the TianGan and DiZhi form a circle, the 10 parts of TianGan divide a cycle evenly into 36° segments (Figure 1A, left), while the 12 parts of DiZhi divide a cycle evenly into 30° segments (Figure 1A, right). Second, the trigonometric function 1-cos(θ) was used to simulate the aforementioned process from birth, growth, prime, and decay to death.

Therefore, the strength of TianGan can be described with the continuous curve generated from the trigonometric function, and each of the 10 parts of TianGan shares a corresponding range (Figure 1B, left). The DiZhi strength can also be described using this function, and each of the 12 parts of DiZhi shares a corresponding range (Figure 1B, right).

As the angular speed of TianGan, 36° per time unit or 10 time units in a cycle, is faster than that of DiZhi, 30° per time unit or 12 time units in a cycle, 1800° or 60 time units are required for both TianGan and DiZhi to reunite at the initiation point, 0°, at the same time (Figure 1C). Because the angular speeds of TianGan and DiZhi are different, they have different strengths within the basic cycle of 60 time units, either in the form of TianGan minus DiZhi (Figure 1D, left) or DiZhi minus TianGan (Figure 1D, right).

Statistical analysis

Pre-processing of data

All data recorded in the Gregorian calendar were transferred to the Chinese T-D time system for further analysis. The conversion took five steps (Table 1). The first step in the conversion was to identify the names of TianGan and DiZhi corresponding to times in the Gregorian calendar. In the second step, each TianGan or DiZhi component was assigned with its range in degrees (as shown in Figure 1A and 1B). The third to fifth steps completed the conversion accurately, using different formulae. The logic underlying these formulae was to address the bias resulting from elapsed time at lower time scales. For example, consider calculating the specific degree value for different time points in day T1. As day T1 ranges from 0 to 36°, the hours elapsed will influence the final specific degree for day T1. There are 24 h or 12 Shichen in one T-D day; thus the first Shichen corresponds to the half-open interval [0 3), and the sixth Shichen corresponds to the half-open interval [15 18).

Statistical analysis

As the time points in the basic time sequence cycle are
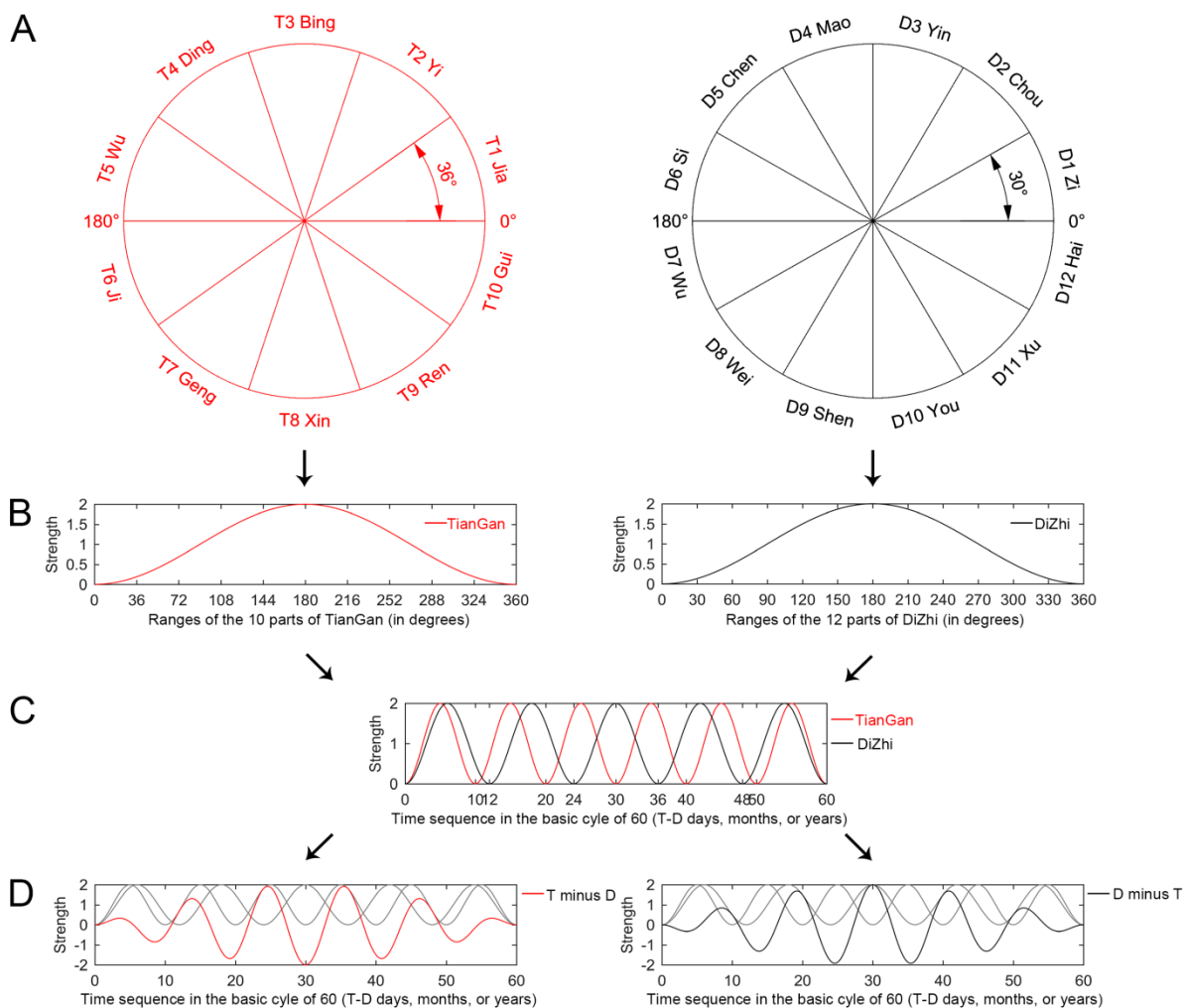
Figure 1. Quantification of TianGan and DiZhi (A) The 10 parts of a TianGan cycle divided evenly into 36° (left), and the 12 parts of a DiZhi cycle divided evenly into 30° (right). The Chinese names for the parts of TianGan and DiZhi go around the respective cycles; (B) The strengths of TianGan and DiZhi are described with a 1-cos(θ) trigonometric function, with different ranges for components of TianGan (left) and DiZhi (right). (C) The least common multiple (60) for TianGan (10) and DiZhi (12); (D) Difference between the strength of TianGan and DiZhi: TianGan minus DiZhi (left) or DiZhi minus TianGan (right), with the gray curves of TianGan and DiZhi as background lines. Here, T represents TianGan and D represents DiZhi.

inhomogeneous, and time points with a gap of 60 are homogeneous, all data were rearranged into the basic time sequence cycle on different time scales. Correlation analyses were conducted in Prism (version 5.0, GraphPad Software Inc.) between major outcome variables (frequencies, intensities, latitudes, longitudes, minimum pressure, and 2-min mean maximum sustained wind speed) and different variables in the T-D time system (TianGan, DiZhi, and their interactions, that is, TianGan minus DiZhi or DiZhi minus TianGan with the opposite sign).

RESULTS

The data in the two calendars and the resulted difference

TC data in the Gregorian calendar and T-D calendar were compared. First, numbers of TCs were compared.

The number of TCs from 1 January, 1956 to 31 December, 2015 labeled using the Gregorian calendar (Figure 2A) were close to that from 5 February, 1956 to 3 February, 2016 rearranged in the T-D calendar (Figure 2B). The difference is provided in Figure 2C. The difference, defined as the difference between the two related values in the two calendars divided by the value in the Gregorian calendar, ranged from -10 to 9.524%, with a standard deviation of 3.293%. Paired t-test of the number of TCs in the two calendars failed to detect significant difference. Second, the 6 h TC records were compared. Data in the Gregorian time system (Figure 2D) also appeared similar to the rearranged data in the T-D time system (Figure 2E). The difference ranged from -6.046 to 6.597%, with a standard deviation of 2.715% (Figure 2F). Paired t-test of the 6 h TC records in the two

Table 1. The steps of converting the Gregorian calendar to a quantified T-D calendar.

Western year 1983		Western month 6		Western day 23		Western hour 12	
Step 1: Identifying the corresponding Tian Gan and Di Zhi							
yT T10-Gui	yD D12-Hai	mT T5-Wu	mD D7-Wu	dT T9-Ren	dD D7-Wu	hT T3-Bing	hD D7-Wu
Step 2: Identifying of the starting point expressed in angles							
T10 324	D12 330	T5 144	D7 180	T9 288	D7 180	T3 72	D7 180
Step 3: Finding the ranks and totals, respectively							
t3 365	r3 140	t2 32	r2 18	t1 12	r1 6	N/A N/A	N/A N/A
Step 4: Conducting the transformation using formulae							
T10+((r3-1+r1/t1)/t3)*36 D12+((r3-1+r1/t1)/t3)*30		T5+36*(r2-1+r1/t1)/t2 D7+30*(r2-1+r1/t1)/t2		T9+36*r1/t1 D7+30*r1/t1		N/A N/A	N/A N/A
Step 5: Determining the accurate angles							
yT 337.76	yD 341.47	mT 163.69	mD 196.41	dT 306	dD 195	hT 72	hD 180

T represents TianGan, D represents DiZhi, t represents total, r represents rank, y represents yearly, m represents monthly, d represents daily, and h represents hourly. Thus, yT represents yearly TianGan. t1, t2, and t3 and r1, r2, and r3 are totals and ranks on different scales of time determined as follows. In Chinese tradition, two hours equal one Shichen, and there are 12 Shichen in one day; therefore, t1 or total1 equals 12. Consequently, the Gregorian hour 12:00 ranks sixth, i.e., 12/2 equals 6 or r1, in the total of 12. Similarly, t2 represents the total of all T-D days in the T-D month; r2 represents the rank of the current T-D day in the T-D month; t3 represents the total of all T-D days in the T-D year; and r3 represents the rank of the current T-D day in the T-D year. The fourth and fifth arrows under the Gregorian hour column were unavailable (N/A), as this level was the lowest level of all time scales in the T-D calendar.
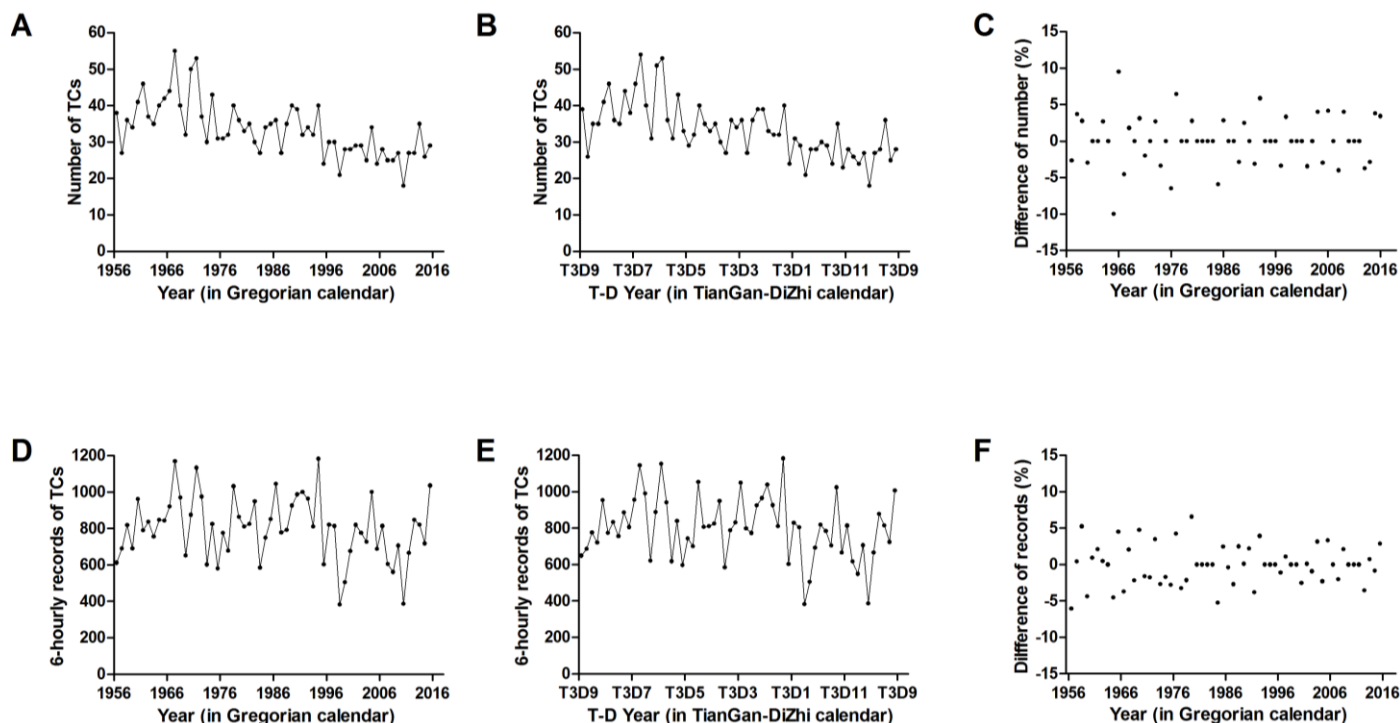
Figure 2. The difference in data between the Gregorian and TianGan-DiZhi calendars (A) The number of TCs from January 1956 to December 2015 presented in the Gregorian calendar; (B) The number of TCs from February 1956 to February 2016 presented in the TianGan-DiZhi calendar; (C) The difference between TC records in the two calendars. The 6 h TC records presented in Gregorian calendar (D) or TianGan-DiZhi calendar (E). The difference between the TC records is also presented in (F).
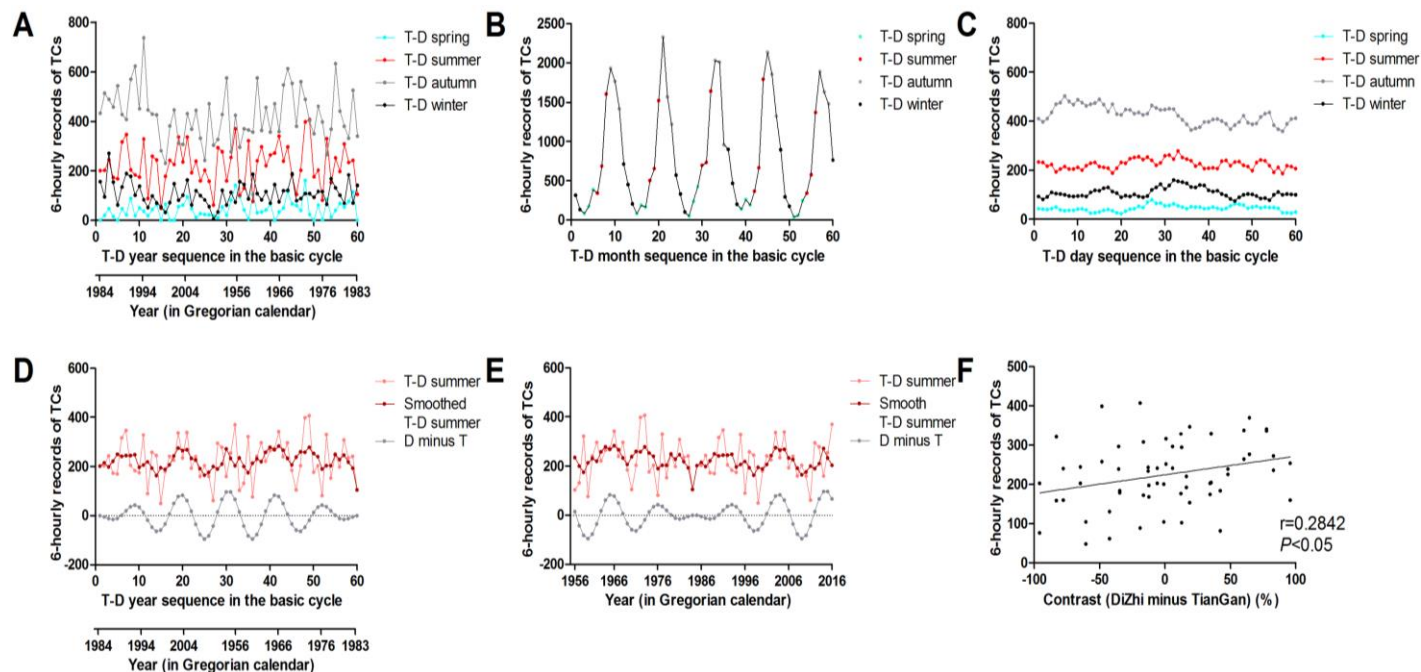
Figure 3. The 6 h TC records rearranged using the T-D calendar to show the irregular variation. The data were presented on the timescales for the T-D year (A), T-D month (B), and T-D day (C). The shapes of the original and smoothed curves for the 6 h TC records in T-D summer were similar to those of the DiZhi minus TianGan curves, shown in the gray line and multiplied by 100 for better comparison, in the basic cycle of years in the T-D calendar (D) or Gregorian calendar (E). Correlation analysis showed that the DiZhi minus TianGan curve strength was significantly correlated with the 6 h TC records in the T-D summer ($P<0.05$) (F).

calendars also found no significant difference.

The correlation between data rearranged within the basic cycle and variables in the T-D time system

The basic cycle in the T-D time system consists of 60 T-D time points on each time scale, in which time point T1D1 is the first and time point T10D12 is the last. All data were rearranged into the basic cycle, with T1D1, on the time scale of year, month, and day, in the first place of the basic cycle, and T10D12 in the last place.

Correlations between TC frequencies and variables in the T-D calendar were calculated first. Results indicated that the number of TCs or their intensities in the T-D time system were not significantly correlated with any variable in the T-D time system. Similarly, the frequencies in the 6 h TC records or their intensities in 60 T-D years in the T-D time system were not significantly correlated with any variable in the T-D time system. Subsequently, the 6 h TC records were deconstructed into four parts using the T-D seasons and rearranged again in the following manner for further examination. On an annual time scale, 6 h TC records in each T-D year were rearranged into the basic cycle, with the year T1D1 (February 1984 to February 1985) in the first place of the basic cycle, and the year T10D12 (February 1983 to February 1984) in the last place. In Figure 3A, note that a horizontal ordinate of

Gregorian calendar was presented below that of the T-D calendar for clarity. Similarly, the 6 TC records for each T-D year were rearranged using the T-D months (Figure 3B) and T-D days (Figure 3C), with T1D1 months or days in the first place and T10D12 months or days in the last place.

Results indicated that the shape of the curve for the 6 h TC records in the T-D summer, either in the original or smoothed form, was similar to the DiZhi minus TianGan curve. The latter was multiplied by 100 for better visual comparison in the T-D calendar in Figure 3D and in the more familiar Gregorian calendar in Figure 3E. The correlation tests showed that the 6 h TC records in the T-D summer were significantly ($P<0.05$) correlated with the DiZhi minus TianGan curve (Figure 3F). However, the 6 h TC records rearranged in T-D months (Figure 3B) or days (Figure 3C) were not significantly correlated with any variable in the T-D calendar.

The correlation of other TC attributes and different variables in the T-D time system were also conducted on the daily timescale. The latitudes (Figure 4A), longitudes (Figure 4B), minimum pressure near the TC center (Figure 4C), and 2-min mean maximum sustained wind speed (Figure 4D) of the 6 h records in the four T-D seasons are presented in the basic cycle of 60 T-D days.

Because TianGan and DiZhi were rivals and interacted, correlation analyses between TC parameters and their interaction were conducted first. Results showed that the
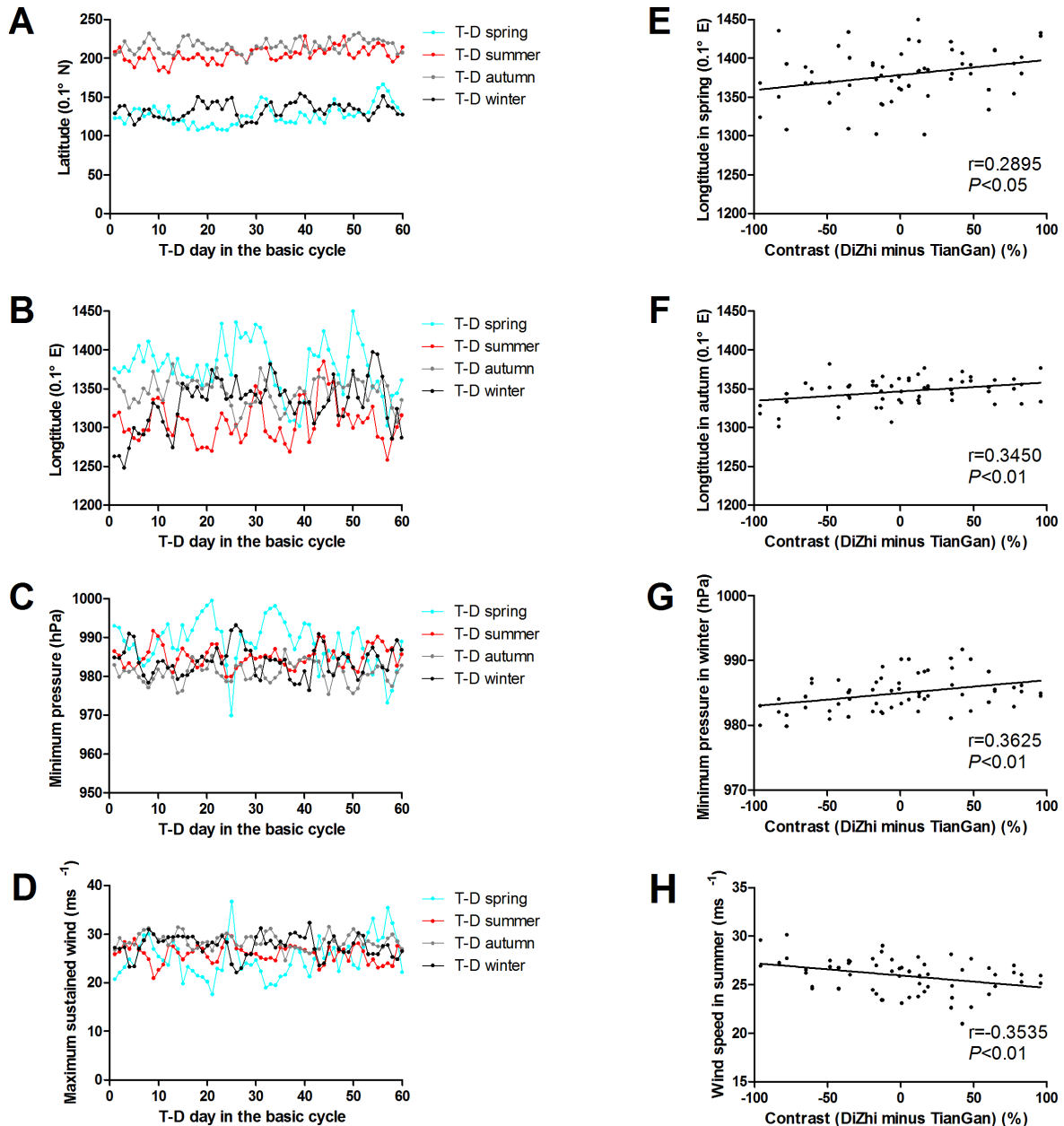
Figure 4. The correlation of TC attributes and different variables in the T-D time system. On the time scale of days, the latitude (A), longitude (B), minimum pressure (C) and wind speed (D) of the 6 h records in the four T-D seasons were present in the basic 60 T-D day cycle. Significant correlations were found between the DiZhi minus TianGan curve and longitudes of the 6 h TC records in T-D spring (*P*<0.05) (E) and T-D autumn (*P*<0.01) (F), minimum pressure in T-D winter (*P*<0.01) (G), and wind speed in T-D summer (*P*<0.01) (H).

latitudes of the 6 h TC records were not significantly correlated with the DiZhi minus TianGan curve. Significant correlation was found between the DiZhi minus TianGan curve and the longitudes for the 6 h TC records in T-D spring (*P*<0.05) (Figure 4E) and T-D autumn (*P*<0.01) (Figure 4F), minimum pressure in T-D winter (*P*<0.01) (Figure 4G), and maximum sustained wind speed in T-D summer (*P*<0.01) (Figure 4H). These indicated attributes were also correlated with TianGan or

DiZhi alone. The strength of TianGan of the T-D days in the basic cycle was significantly correlated with longitudes in T-D autumn (r= -0.3044, *P*<0.05), minimum pressure near the TC center in T-D spring (r=-0.3570, *P*<0.01), 2-min mean maximum sustained wind speed near the TC center in T-D spring (r=0.3152, *P*<0.05), and T-D winter (r=-0.2987, *P*<0.05). The strength of DiZhi was significantly correlated with latitudes in T-D spring (r=0.2954, *P*<0.05), minimum pressure in T-D summer

(r=0.3931, *P*<0.01), and maximum sustained wind speed in T-D summer (r=-0.3636, *P*<0.01).

DISCUSSION

The T-D calendar was quantified for the first time in this study. Using this quantified time system, the seemly irregular variations in TCs over the WNP showed some previously unrecognized order. Notably, there were several significant correlations in T-D summer. The results showed that the 6 h records (Figure 3F) were positively correlated with DiZhi minus TianGan, and wind speeds in T-D summer were negatively correlated with DiZhi minus TianGan (Figure 4H) or DiZhi alone. Two questions were gotten from these observations:

1. What is the nature of such difference induced by DiZhi minus TianGan?
2. What are the underlying mechanisms for these correlations?

First, the nature of such difference between TianGan and DiZhi arises from their interactions. As discussed previously, in materials and methods, TianGan is related to Yang, while DiZhi is related to Yin. Because Yang and Yin are rivals in Chinese philosophy, they can be subtracted from each other and the difference equals their interaction, in modern terms.

Therefore, the value of DiZhi minus TianGan is the net value of DiZhi. Consequently, a positive net value indicates that DiZhi or Yin is stronger than TianGan or Yang; and a negative net value indicates that DiZhi or Yin is weaker than TianGan or Yang. Yang is related to warm and hot climates or conditions, while Yin is related to chilly and cold climate or conditions. Because on the one hand the TCs generally formed over warm sea areas (Gray, 1998), where Yin is much weaker than Yang; on the other hand, the larger the subtracted value (DiZhi minus TianGan) was the more records of TCs occurred," it is logical to infer that a high net value of Yin is required to reach a balance of Yang and Yin.

The negative correlation between wind speed in T-D summer and DiZhi minus TianGan (Figure 4H) or DiZhi alone suggests that most of these 6 h records belonged to low-intensity TCs. For other significant correlation, explanations are not as readily available, as only some seasons showed some order, which indicated there might be some other unknown mechanisms. More related researches using the quantified T-D calendar are required.

These correlations alone might be useful for limited prediction. For example, because the number of 6 h TC records in T-D summer was significantly correlated with variables in the T-D time system on an annual timescale (Figure 3D, E, and F), it would be useful to predict TC frequencies in T-D summer across different T-D years. These observations might be also helpful for forecasting

models. Currently, five numerical models (Halperin et al., 2013) have been used with various inputs. It is possible that better results will be achieved with inputs modified in advance using the correlations provided in this work. For example, the significant correlation between spatial parameters, that is, latitudes and longitudes, and variables in the T-D time system will assist numerical models in predicting the location of genesis, and even tracks, of TCs.

Conclusion

The T-D calendar has been primarily viewed as a tool to record time. However, in this study, the T-D calendar was used for the first time as a quantifiable tool in TC analysis. The raw TC data was appropriately organized in the quantified T-D calendar, which provided a proper statistical analysis and helpful discovery. Therefore, we suggest that the quantified T-D calendar might also be useful for analyzing events in more disciplines.

CONFLICT OF INTERESTS

The author has not declared any conflict of interests.

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Full Length Research Paper

Physical and commuting characteristics of selected peri-urban settlements in Kaduna, Kaduna State, Nigeria

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Cities in Nigeria have been experiencing exceptional changes in terms of population and spatial extent. The rapid rate of these growths and the inadvertent expansion of cities have resulted in several negative consequences. This research is aimed at evaluating the physical and commuting pattern of selected peri-urban settlements. The objectives are to examine the availability of utilities, services and infrastructure; assess the physical and spatial characteristics; and appraise the commuting characteristics between the city and the peri-urban settlements. The research design adopted is the mixed research method which involves the investigation of patterns or sequences of growth and changes over a given period of time (time series), and the description of existing conditions in a given area. The results shows that the most used mode for commuting between the peripheral settlements and the city centre is the bus with (24%), while the least is the lorry/trailer with a score of (2.1%). The major factors of influence for the trips are work, with (23%), while job seeking is the least with (3.5%). The study also reveals that the peripheral areas of Kaduna metropolis suffer serious traffic congestion caused by increased number of private vehicles on inadequate road network with finite capacity, hence, the need to enforce compliance with basic development control standards, and the use of advanced technology such as trip matching and the internet for carpooling and ride sharing, thereby increasing the potential to reach the critical mass of users.

Key words: Peri-urban, traffic congestion, commuting, settlements.

INTRODUCTION

The urban fringe constitutes an important interface in settlement continuum and for a developing country such as Nigeria. It provides a buffer for people, urban physiology, and economy and in particular livelihood and services. The fringe is seen as the frontier in space where the returns to land from traditional and customary urban land uses are roughly equal to the returns from traditional and customary rural land uses (Sanusi, 2010). It is space located outside the limit of the city (Avram, 2009; Saxema, 2008). Such area reflects the pressure of

the city on the surrounding neighbouring space (Avram, 2009). The fringe is also characterised by random, separate, and fragmented growth (Alabi, 2009). Peripheral areas also mean an evolution or interaction zone, where both urban and rural activities lie contiguous to each other and landscape element changes rather rapidly, which are influenced largely by human actions (Douglas, 2006). These areas include protected areas, forested hills, conserved woodlands, major agricultural lands, and important wetlands, which are critical to the survival of the urban residents. Peri-urban area is not only a zone facing the direct effects of the land demands of urban expansion and pollution, it is also an inclusive market-related sphere of influence that is easily identifiable with respect to the handling of agricultural and natural resource harvests (Simon et al., 2006).

In economic term, the fringe is seen as a space where livelihoods depend on natural resources (Adesina, 2007). Hence, 'land is the characteristics to agricultural activities and the inhabitants' way of life is specifically rural' (Avram, 2007). As a result, people who reside in the fringes live in the economic realm of the city, but are not attracted to urban economy (Taleshi, 2009). Largely, fringe settlements 'develop outside of government control and do not follow strictly formal and traditional urban planning and development processes' (Hogrewe et al., 1993). The loss of arable agricultural land to urban growth in developing regions is flagged to be a result of prevalent anthropogenic activities. Similarly, the unprecedented transformation of natural landscapes into urban settings significantly affects the natural functioning of ecosystems. Hence, urbanization has been the foremost human led land-use anthropogenic activity with huge and irreversible impacts. It is a major force that drives changes such as land-use land-cover change (LULCC), biodiversity loss, the biogeochemical cycle, hydrological systems, and climate. Another prominent agent that can be linked to the unprecedented growth witnessed in urban expansion is population increase (Mahmoud et al., 2016).

The year 2008 has been celebrated globally as the year in which the percentage of the world's population living in towns and cities supersedes that of those living in rural areas (Mabogunje, 2008). In fact, the world has developed faster than initially predicted by Rev. Thomas Robert Malthus in 1798. "He argued that one day the population of the world would outstrip the globes ability to feed it", because population expanded geometrically, while subsistence increases only at an arithmetic ratio which could lead to societal ruins. In 1950, there were 86 cities in the world with a population of more than one million. Today, there are over 400 cities that are one million and above, and by 2015, this figure is expected to reach at least 550 and Africa has been the region with the fastest rate of urbanization in the world (Badiane, 2006). Cities in a country like Nigeria have been experiencing exceptional changes in terms of both population and spatial extent. The instruments for rapid

city expansion in the developing countries are rural-urban migration and natural increase. In 1976, one third of the world population lived in cities and 30 years later (2006), this rose to one-half of the entire human kind (Tibaijuka, 2006) and by the target year for the Millennium Development Goals (MDG'S), cities in the world are expected to grow to two-third or 6 billion people by 2050 (UN Habitat, 2012; Aitieri et al., 2014).

Notwithstanding the economic benefits that comes with it; the rapid rates of growth and inadvertent expansion of cities have resulted in several negative consequences, especially in developing nations. These can be seen in the emergence of shanty's, illegal occupation of residential plots, increasing vehicular traffic congestion, worsening infrastructure and shortfalls in service delivery among others, which consequently contributes to land use change. The rate of urban growth and its encroachment into agricultural land use is unprecedented which is a popular trend and pattern in most countries (Belal and Moghanm, 2011; Long et al., 2007).

Rapid growth in urban areas which is expected to be pervasive for the ecological landscape of urban regions in developing nations will remain as one of the critical concerns of global change in the 21st century that will distress the human wellbeing. This increasing rate of urban growth and land use changes endangers the ecosystem of large cities in advanced countries and giving rise to many landscape and ecological challenges such as flooding, shortage in portable water and food supply, and negative microclimatic condition that are feared to impede sustainable human development (Liu et al., 2007; Wolch et al., 2014). As cities spread out into countryside advancing like waves on a beach, the land on the edge, be it farmland, grassland, or forest is converted to urban uses (Bryant et al.,1982). As land allocation speeds up in the peri-urban areas, a land market emerges with changes in land use, changes that have resulted into haphazard and uncontrolled growth in most metropolitan areas. These areas have grown in spatial extent and density manifested by natural expansion of extent of built-up areas to their immediate rural surroundings. In this case, most peripheral settlements in close proximity to the urban centres are facing urban expansion.

In this study, attention is focused on evaluating the physical and commuting pattern of selected peri-urban settlements. The objectives of this paper are to examine the availability of utilities, services and infrastructure; assessing the physical and spatial characteristics of the peri-urban settlements; and appraising the commuting characteristics between the city and the peri-urban settlements.

METHODOLOGY

Study area

Kaduna metropolis is located between Lat. N10°23' and 10°43' N
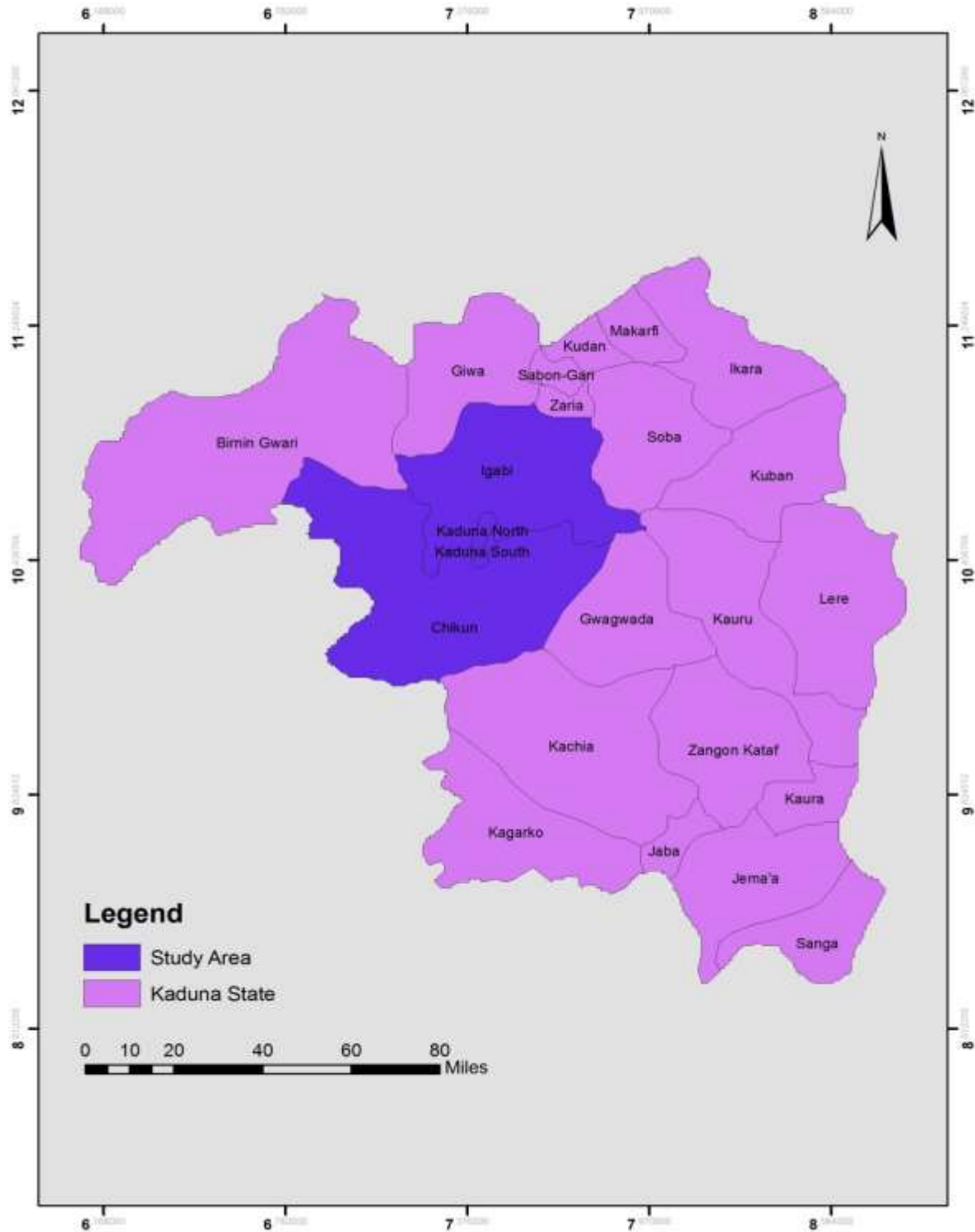
Figure 1. Kaduna metropolis.

and Long. 7°17' and 7°37'E. The study area is tightly drawn around Kaduna's developable area. The area consist of four Local Government Areas, namely: Kaduna North and Kaduna South, and parts of Igabi and Chikun Local Governments and about 12,347 km^2 (Figure 1).

The core geology is mostly of the metamorphic rocks of the Nigerian Basement Complex. Weathering activities with fluvial erosion influenced by the bio-climatic nature of the environment have developed the characteristic high undulating plains with passive interfluves (Mortimore, 1970 cited in Umaru, 2006).
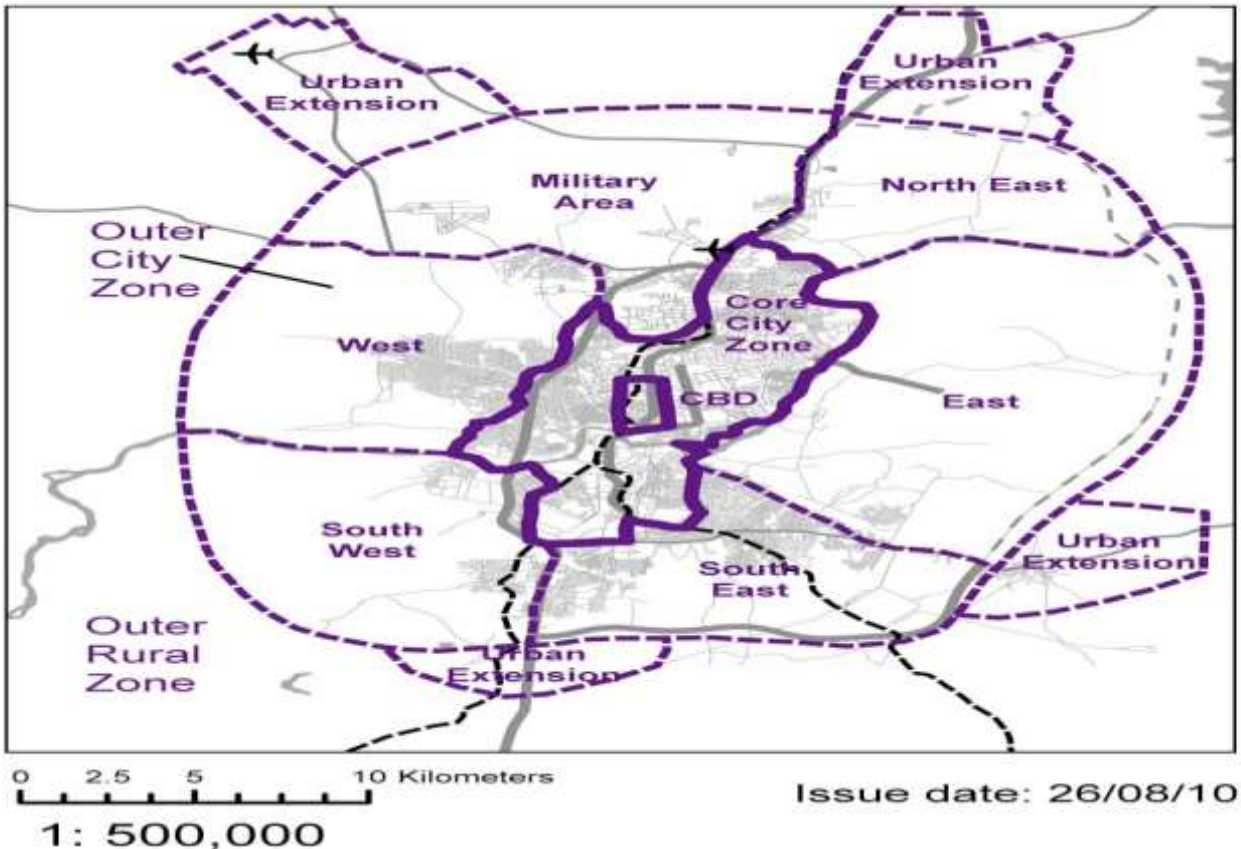
Figure 2. Kaduna extent of the metropolis and the peripheral areas.
Source: Max Lock (1967).

However, the local relief of the area includes rocky granite residuals form inselberg of varying shapes and sizes. This could be found around the Kufena and Kagoro Hills and Dutsen WaiKudaru Ring complex standing out very conspicuously in the southern part (Ashafa, 2004).

The state forms part of the country's traditional melting pot (Ashafa, 2004). Among the major ethnic groups are the Hausa and Kurama to the North and Northeast, respectively. "*Nerzit*" is now used to refer to the Jaba, Kamuku, Gwari and Kadara in the West, Marwa and Chawai Kaje, Kaninkon, Koro, Kamanton, Kataf, in place of the disparaging term "Southern Zaria people". Similarly, the term "*Hausawa*" is used to refer to the people of Igabi, Ikara, Giwa and Makarfi LGAs, which are mostly inhabited by the "Maguzawas. In the north, they practice Islam but the majority of the people in the Southern LGAs profess Christianity (Kaduna State Newscope, 2004), the 2006 census provisional figures put the population of the state at 6,066,562 (National Population Commission, 2006).

The major sources of water in the urban areas are tap and wells. But there is acute water shortage in some of the neighborhoods' of the urban centres. In some cases, poorly treated or untreated water is released by the Water Board, periodically. In the rural areas, wells, boreholes, and streams are the major sources of water. These areas experience acute water problem during the dry season when the sources dry up. People trek long distances for water and much of what is gotten is not treated.

River Kaduna is the main source of water intake for domestic as well as industrial purposes in Kaduna metropolis. Over 50 functional industries depend on the river for their production processes through the Kaduna State Water Board with a capacity of 3,000,000 L per day (Bello, 2000).

In determining the spatial extent of the metropolis and the peripheral areas, the extent of the planning area (as provided by the Kaduna State Urban Planning and Development Authority) of 35 km radius will be used as the boundary of the study. The inner limit (built up areas) of 20 km radius as proposed by Max Lock (1967) shall form the basis for the work. Consequently, developments that exist between the extent of the built up areas, that is, 20 km radius as provided by Max Lock (1967) and the planning area forms the extent of the peripheral areas for the work (Figure 2).

The research design adopted for this work is the mixed research method (Developmental and Descriptive) which involves the investigation of patterns or sequences of growth and changes over a given period of time, and the description and interpretation of existing conditions in a given area. This is because the survey design proves to be effective in seeking the views of people on issues that affects them. The population for this study includes the population of the household heads in the sampled peripheral areas, National Space Research and Development Authority (NASRDA), National Centre for Remote Sensing (NCRS), National Population Commission (NPC, 2016) and Kaduna State Urban Planning and Development Authority (KASUPDA) (Figure 3).

The peripheral areas located in the four local government areas, namely; Rigachikun, Barakallahu, Kawo and Kawo New Extention, Sabon Gida, Rigasa, Hayin Danmani, Unguwan Gwari, Unguwan Kaji, Rafin Guza, Television village, Sabon Tasha, Narayi, Gonin Gora, Unguwan Romi, Mararraban Rido, Kudenda, Tsaunin Kura, Unguwan Gimbiya, Unguwan Boro, Unguwan Sunday, Nasarawa,
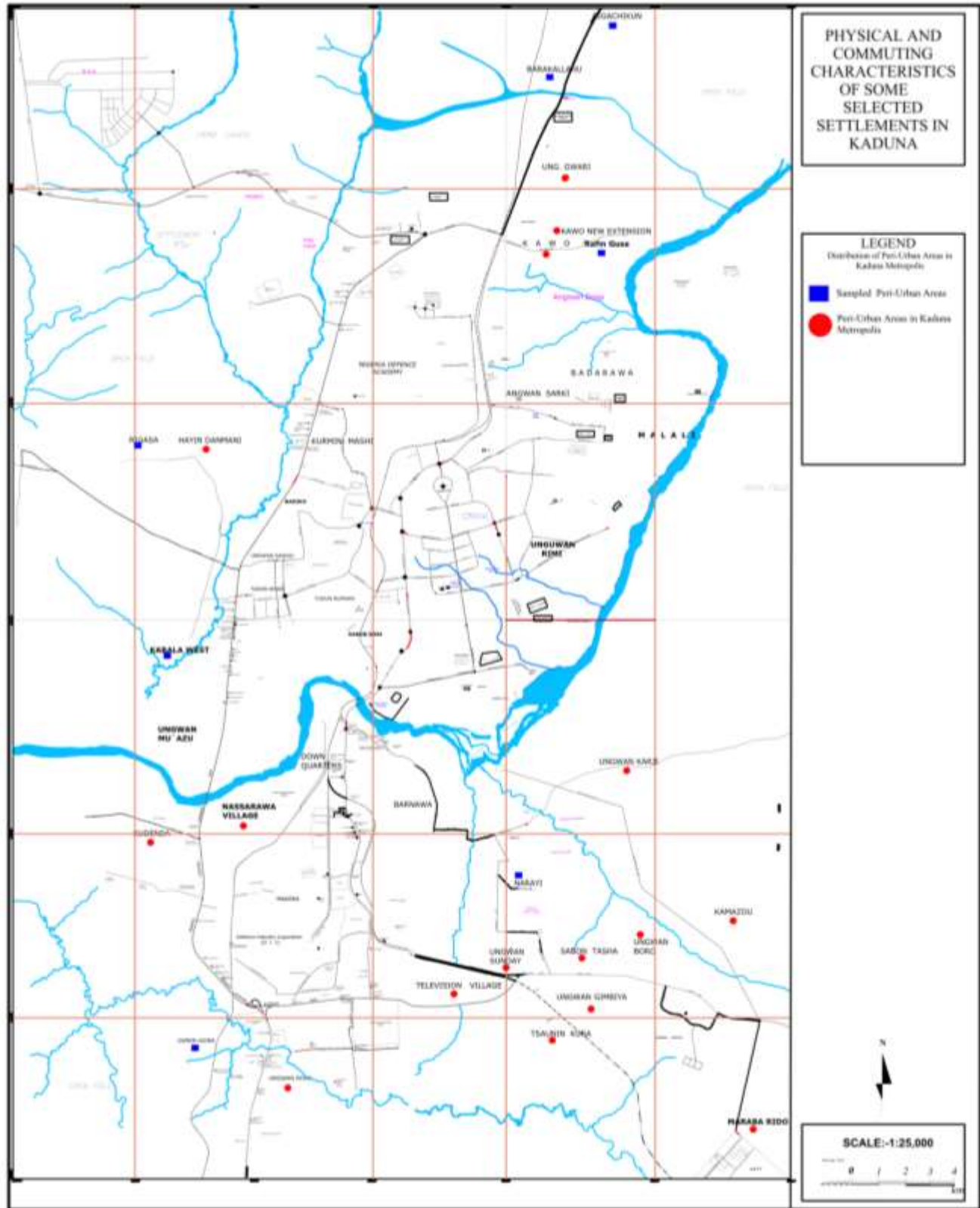
Figure 3. Distribution of peri-urban areas and the six sample settlements in Kaduna metropolis.

Unguwan Muazu/Kabala West, and Kamazou giving a total population of 682,625 people (NPC, 2006), form the sampling frame

Table 1. Distribution of population in the sampled settlements.

Peripheral area	Population	Households	Percentage of total population	Percentage of total households
Rigachikun	15,238	1905	2	2
Barakallahu	4,216	527	1	1
Rigasa	149,600	18,700	22	22
Kawo	21,352	2,669	3	3
Kawo N. Extension	5,229	634	1	1
Hayin Danmani	12,354	1,544	2	2
Sabon Gida	2,150	269	0.3	0.3
Unguwan Gwari/Rafin Guza/Unguwan Kaji	21,074	2,634	1	1
Unguwan Gimbiya	3,293	412	1	1
Unguwan Boro	5,191	649	1	1
Kamazou	12,678	1,585	2	2
Gonin Gora	17,553	2,194	3	3
Mararraban Rido	1,154	144	0.2	0.2
Narayi	46,278	5,785	7	7
Sabon Tasha	53,270	6,659	8	8
Unguwan Television	55,407	6,926	8	8
Tsaunin Kura	2,476	309	0.3	0.3
Unguwan Sunday	48,670	6,084	7	7
Unguwan Muazu/Kabala West	64,530	8,066	9	9
Nasarawa	120,222	15,028	18	18
Kudenda	1,986	248	0.3	0.3
Unguwan Romi	18,704	2,338	3	3
Total	682,625	85,309	100	100

Source: Author's Field Work (2012).

for the study (Table 1).

Data requirement, sources and characteristics

The data for this study involves Landsat MSS (Multispectral) Satellite image scenes of Kaduna for 1990, 1995 and 2000 at 32 m resolution, Nigeria-Sat 1 image of 2005 at 32 m resolution, and Quick Bird image of 2010 at 1 m resolution. These were obtained from the National Centre for Remote Sensing Jos, Plateau State and the National Space Research and Development Agency (NASRDA), Abuja. Kaduna metropolitan map at scale 1:50,000 was obtained from KASUPDA. Data on the population increases over the years; physical and commuting characteristics between the city centre and the peripheral areas were acquired. Finally, data on the application of development control within the peripheral areas were also obtained through field investigations, which specifically include the spatial characteristics like measurement of the infrastructures within the peripheral areas.

RESULTS AND DISCUSSION

Spatially, the location of the sampled peripheral areas within Kaduna Metropolis shown in Table 2 indicates that the distance between Rigachikun to the central market which is within the Central Business district is 10.1 km, Rigasa to the central market is 5.4 km, Gonin-Gora is 14.1 km, Narayi is 10.6 km, Unguwan Muazu/Kabala

West is 4.5 km, and Rafin Guza is 8 km, respectively.

To the south of the River Kaduna, the expansion was initially fuelled by industrial growth attracting large numbers of in-migrants. Although many of the textile factories have closed down; the formal and informal opportunities north of the river and the few industrial concentrations south of the river continue to underpin Kaduna's role as one of Nigeria's largest cities, only behind Lagos, Kano and Abuja. North of the river, subsequent to the growth of the new district of Sabon Gari to the west of Tudun Wada, development of the Western districts of Rigasa, Afaka and Ung. Mu'azu was stimulated by the building of the western expressway by the Federal Government in the late 1970s as part of the new North/South trunk road linking Kano, Kaduna, Abuja and a Niger River crossing at Lokoja. Expansion of development to the east has been hampered by lack of access bridges over the Kaduna River. The potential for dramatic change in this pattern of growth has increased with the recent construction of the New Makarfi Bridge and plans for the New Millennium City that opens up the development potential east of the river, as well as the recent award and completion of the Gobarau Road Bridge and approach roads.

The population of the sampled peripheral areas which

Table 2. Kaduna sampled peripheral areas spatial location.

Area	Distance from the central market (km)
Rigachikun	10.1
Rigasa	5.4
Gonin Gora	14.1
Narayi	10.6
Ungwan Muazu/Kabala West	4.5
Rafin Guza	8

Source: Author's Field Work (2012).

Table 3. Kaduna sampled urban peripheral areas' transport infrastructure.

Area	Tarred roads (km)		Untarred roads (km)	Foot-paths (km)
	Good condition	Not in good condition		
Rigachikun	3.1	1	5	5.4
Rigasa	4.2	6.3	4	3.6
Gonin Gora	3.5	1	5.8	3.1
Narayi	5	6.2	7	3.6
Ungwan Muazu/Kabala West	5.43	6	4.65	4.3
Rafin Guza	2	2.4	4.1	3.9
Ungwan Boro	2	4.7	4.91	2.4

Source: Author's Field Work (2012).

to a large extent was fuelled by the communal clashes in Kaduna in 2000 and 2002 and has had the effect of changing settlement patterns and promoting the expansion of the city in rapidly unplanned residential development in the south (Christian) and the west and north (Muslim). It must be emphasized that these developments are not exclusively one religion or the other. There is still much mixed living in Kaduna's residential areas.

This has propelled the growth of settlements like Afaka, Mando, National Eye Center, Panteka, Rigasa, Bakin Ruwa, Ugwan Muazu, Nasarawa, and Kudenda which hitherto serves as an industrial layout. This has extended until it intersected with the Abuja express way. Towards the eastern part, development in this direction has spread through the road linking NNPC and the East West to Unguwan Boro, Kamazou, Janruwa, Sabon-Tasha, and Rido settlements. It is the largest single concentration of peripheral development in all the direction of growth of Kaduna metropolis. Finally, in the south along Abuja express way, unplanned urban development has reached about 4 km from the point of express intersection to Goni Gora.

Transport Infrastructure

The analysis in Table 3 on the transport infrastructures in the sampled peripheral areas indicates that 53 km of the roads in the peripheral areas are tarred. 25 km of the tarred roads are in good condition, while 28 km are in various state of disrepair. Similarly, 35 km of the roads are untarred and 26.3 km of the area are being accessed through footpaths.

The number of kilometers of road that are untarred and those areas that are accessed by only footpath compete favourably with those that are tarred and the narrow nature of such roads depicts clearly the absence of plan in the area; and thus, its unplanned outlook. The transport infrastructure of significance in most peripheral areas is the major highways linking Kaduna to other parts of the country in all directions. To the north of the town is the federal trunk "A" highway linking Kaduna, Zaria and Kano. To the west of Tudun Wada, is the western bypass which was constructed by the federal government in the late 1970's as part of the New/South trunk road linking Kano, Kaduna, and Abuja. To the south east, is the road linking Kaduna to NNPC Kachia and then Abuja. Apart from the fact that these highways circulation within the settlements themselves is very poor, most of the roads are not motorable particularly during the raining season.

Social Infrastructure

Social infrastructure consist of several educational and health institutions. The institutions in the periphery are however only capable of rendering primary and to some

extent secondary services in these areas. They are however inadequate in terms of quantity and quality to cater for the growing population. The population therefore depends on infrastructure within the town itself. The high rate of population growth and urbanisation has placed a strain on available infrastructure within these areas and on Kaduna town. Some utilities and services, such as electricity, pipe-borne water and fire and postal services are available on skeletal basis. This is shown in Table 4.

The table shows that, there are a wide range of facilities and services that are either absent completely or are inadequate in the sampled peripheral areas. Amongst others, the ones that are absent include the postal agency, civic centre, fire service, recreation ground, and refuse depot. Similarly, those that exist but are inadequate include nursery (65%), primary school (64%), secondary school (57%), shopping centre (90%), police post (82%), health centre (95%), local market (79%), Motor Park (70%), commercial bank (89%), petrol filling station (33%), and cemetery (65%).

This shows that, lack of planning in the peripheral areas have greatly affected the provision of basic facilities and services in the area. For instance, settlements like Rigasa with a population of 149600 can only boast of one secondary school, a nursery and primary school which is far below the standard expected. This means that residents have to travel long distances to meet up with some of their daily needs, especially the schools, shopping and for recreational purposes amongst others, this of course informed the planlessness in those areas.

Commuting between Kaduna metropolis and the peripheral areas

Daily commuting between Kaduna metropolis and the sampled peripheral areas are influenced by the paucity of infrastructures at the peripheral areas, and to a large extent the unplanned settlements, as most of the commuting were geared towards meeting up with their daily work schedules or for buying some specialized goods and services or the sales of some agricultural produce, which may not all be consumed at the peripheral areas where there are fewer people with less income. Some of the commuters go to the city in search of jobs, as most of the infrastructures that enable job creation are located in the metropolitan area, hence, transportation as a functional variable in the history of a city, plays a significant role in the mass movement of people and goods and services. The functionality of the system is a sign of uniqueness of the city, because people tend to move from one point to the other using roads, rail and water in conjunction with the facilities. The city does not operate intra-city train and water transport systems, the only means of transport is the road (Figure 4).

The survey results in Table 5 on modes, factors of influence and trip frequencies in the sampled areas indicate that the most used mode for commuting between the peripheral areas and the city centre is the bus (24%), motorcycle (20%), private car (6.8%), bicycle (2.6%) and the least which is the lorry/trailer (2.1%), respectively. The major factors of influence for the trips are work (23%), religious (12.5%), medical (9.5%), social visits (6.8%), commercial activities like shopping (6.8%), and to source for job (3.5%). The trips that occur daily has the highest frequency (28%), weekly (16%), monthly (8.1%), occasionally (5.3%), seasonally (3.1%), and finally annually (1.5%), respectively.

The implication of this however, is that people commute from the peripheral areas to the city centre on bus daily for work and spent a lot of time on transit due to traffic gridlocks that are experienced during the morning and evening peak hours, and that could have informed the reason why they had earlier indicated that the mode of commuting to and from the peripheral areas are grossly inadequate and un-conducive compared to the growing population of such areas.

City peripheries are the growth fronts. It is in the peripheries that most rapid physical growth impulses occur either in planned or spontaneous manner. Incidentally, it is one of the ironies of city history that some of the efforts made to cure the evils originally caused by city growth have enabled cities to grow more rapidly. This is particularly true about the provision of utilities like electricity and water to peripheral locations which have the effect of producing accelerated physical developments in the areas affected, which is the true situation of what is happening in Kaduna metropolis.

Conclusion

Undoubtedly, the peri-urban areas of Kaduna metropolis are fast transforming from an agricultural community to an urban centre and local environmental problems of various magnitudes are becoming prominent. Urgent and coordinated measures must be taken to contain the frightening rate of expansion of the built-up area into adjourning farmlands. The progressive loss of these farmlands to urban use means a continuous reduction of the most valuable agricultural lands in the peri-urban areas. As the metropolis expands, infrastructure requirements continually increase and expand spatially. At present, these are managed by the state agencies or local administrations with no mechanism for overall coordination across the metropolis.

Peripheral areas of Kaduna and the metropolis at large suffer serious traffic congestion caused by the ever increasing number of private vehicles on inadequate road network with finite capacity and hence, the need to enforce compliance with basic development control standards. Specifically, this will involve the upgrading and

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Table 4. Social infrastructure, utilities and services.

Area	Population	Nursery			Primary			Secondary			Commercial bank		
		Existing	Standard	Deficit	Existing	Standard	Deficit	Existing	Standard	Deficit	Existing	Standard	Deficit
Rigachikun	19,454	2	2	-	2	3	1	2	1	-	-	2	2
Rigasa	149,600	1	15	14	2	10	8	1	7	6	-	4	4
Gonin Gora	17,353	2	2	-	1	2	1	1	1	-	-	2	2
Narayi	46,278	3	5	2	2	4	2	1	2	1	-	4	4
U-Muazu/ K-West	56,113	3	6	3	1	5	4	1	2	1	2	5	3
Rafin Guza	9,514	-	1	1	1	1	1	-	1	1	-	1	1
Total (%)	298,312	35	100	65	36	100	64	43	100	57	11	100	89

Facilities

Area	Population	Recreation ground			Shopping centre			Health centre			Refuse depot		
		Existing	Standard	Deficit	Existing	Standard	Deficit	Existing	Standard	Deficit	Existing	Standard	Deficit
Rigachikun	19,454	-	2	2	-	2	2	-	2	2	-	2	2
Rigasa	149,600	-	4	4	-	5	5	-	4	4	-	6	6
Gonin Gora	17,353	-	2	2	-	2	2	-	2	2	-	2	2
Narayi	46,278	-	4	4	2	5	3	1	6	5	-	4	4
U-Muazu/ K-West	56,113	-	5	5	-	6	6	-	7	7	-	5	5
Rafin Guza	9,514	-	1	1	-	1	1	-	1	1	-	1	1
Total (%)	298,312	0	100	100	10	100	90	5	100	95	0	100	100

Civic uses / Services

Area	Population	Civic centre			Church			Mosque			Local market		
		Existing	Standard	Deficit	Existing	Standard	Deficit	Existing	Standard	Deficit	Existing	Standard	Deficit
Rigachikun	19,454	-	2	2	-	2	2	5	2	-	-	1	1
Rigasa	149,600	-	8	8	-	4	4	18	8	-	1	4	3
Gonin Gora	17,353	-	2	2	6	2	-	-	2	2	1	2	1
Narayi	46,278	-	6	6	10	5	-	-	5	5	1	4	3
U-Muazu/K-West	56,113	-	7	7	2	5	3	7	5	-	-	5	5
Rafin Guza	9,514	-	1	1	1	2	1	4	2	-	-	1	1
Total (%)	298,312	0	100	100	95	100	5	141	100	41	21	100	79

Services

Area	Population	Motor park			Police post			Petrol filling station			Postal agency		
		Existing	Standard	Deficit	Existing	Standard	Deficit	Existing	Standard	Deficit	Existing	Standard	Deficit
Rigachikun	19,454												
Rigasa	149,600	-	1	1	1	2	1	2	2	-	-	1	1
Gonin Gora	17,353	1	2	1	1	4	3	2	8	6	-	2	2

Table 4. Contd.

Narayi	46,278	1	2	1	1	2	1	6	2	-	-	1	1
U-Muazu/K-West	56,113	-	2	2	1	4	3	-	3	3	-	2	2
Rafin Guza	9,514	-	2	2	1	5	4	4	5	1	-	2	2
Total (%)	298,312	-	1	1	-	1	1	-	1	1	-	1	1
		30	100	70	28	100	82	67	100	33	0	100	100

		Services		
		Existing	Standard	Deficit
Rigachikun	19,454	1	2	1
Rigasa	149,600	1	8	7
Gonin Gora	17,353	1	2	1
Narayi	46,278	1	2	1
U-Muazu/K-West	56,113	1	2	1
Rafin Guza	9,514	1	1	-
Total (%)	298,312	35	100	65

Table 5. Modes, factors of influence and trip frequencies of peripheral areas in relation to Kaduna City Centre.

Traffic origin	Total No. of people interviewed	Modes						Factors of influences						Trip frequencies		
		Bus	Private car	Lorry/Trailer	Taxi	Motorcycle	Bicycle	Work	Commercial goods	Job seeking	Social visits	Education	Newspaper circulation	Daily	Weekly	Monthly
Rigachikun	120	52	21	7	18	20	2	20	7	30	22	32	2	86	32	2
Rigasa	935	489	96	15	132	185	18	444	154	177	111	39	10	779	147	14
Narayi	290	138	82	4	23	40	3	148	55	45	21	8	13	205	73	12
U-Muazu/K-West	350	144	85	4	73	42	2	164	97	42	21	12	14	255	86	9
Gonin-Gora	110	53	34	1	16	6	1	48	20	23	12	3	4	80	27	3
Rafin- Guza	60	25	10	4	12	8	1	28	14	12	3	1	2	45	13	2

Source: Author's Field Work (2012).

extension of transport infrastructure to the peripheral areas, promotion of the use of public transport by improving and extending the range and coverage of services and the use of technology to advertise car sharing and carpooling on all modes and discourage the use of private vehicles by the introduction of congestion charges, financial disincentives, regulations and other similar interventions. This will improve the capacity of the road networks in a manner consistent with international traffic management measures.

RECOMMENDATION

The world is experiencing one of the fastest rates of urbanization ever recorded; the experience has been unique in scale, pervasiveness and in historical antecedents. Several cities continue to expand their spatial boundaries to the peripheries in order to cater for high population growth and migration. Although the expansion of cities is unavoidable under strong developmental pressures, the increasingly uncoordinated manner
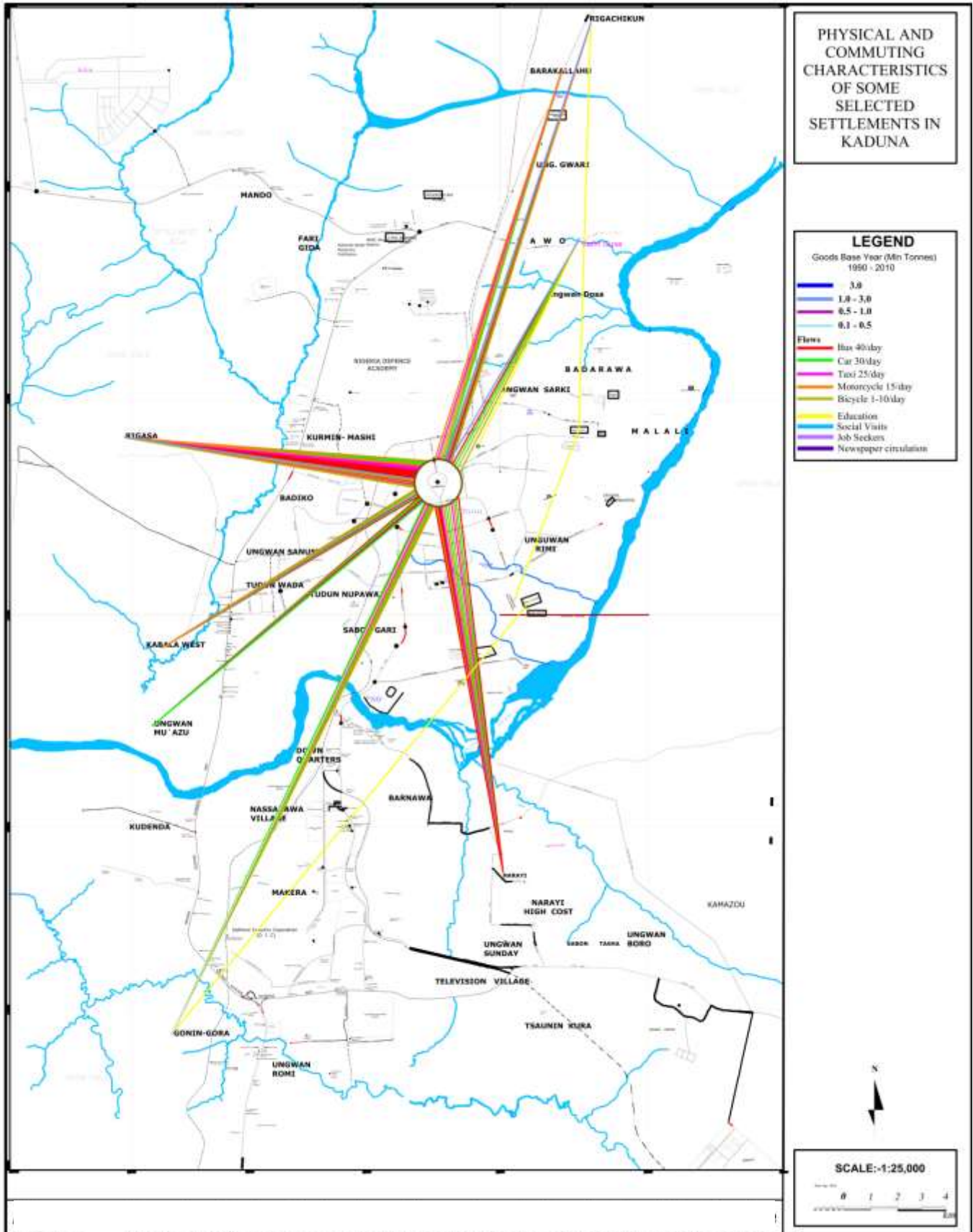
Figure 4. Flow analysis: Peri-urban areas in relation to the city centre.

particularly in developing countries of these expansions has induced the spill over of environmental degradation across metropolitan areas. These problems are enormous and varied. Millions have been left to live for prolonged periods in makeshift urban slums, suffering from poverty of income, health, nutrition, and safety. Constant threats of food and water scarcity have been brought about by climate change, unsustainable resource use, and inadequate planning. Cities are increasingly unsustainable vulnerable and insecure, and therefore achieving sustainability and resilience for cities has to be high on any government's agenda.

Ecosystem services can address many of the challenges that cities increasingly face, clean air, safe drinking water, and protection from climate change effects are all highly relevant to human development in cities, and many forms of poverty are caused or exacerbated by a lack of access to these ecosystem services. Furthermore, cities consume tremendous amounts of resources and thus generate large amounts of waste and emissions. These negative externalities of urban growth are borne disproportionately by the income poor, who do not have access (or the means) to procure clean drinking water and health services. The role of natural areas in providing catchment for stable and cheap drinking water cannot be overemphasized; almost a third of the 100 largest cities have proximate natural areas that provide this service. Furthermore, green spaces in or near cities also deliver services such as air purification, temperature regulation, groundwater recharge, and cultural services including aesthetics and recreation, all leading to healthier lifestyles. Urban biodiversity and ecosystems deliver myriad other benefits, from underpinning social and economic development to climate change mitigation and adaptation. Wetlands can treat storm water runoff and also offer biodiversity and recreational services. Local food production in cities is an exciting and evolving dimension of cities, and it can both decrease the emissions externality of cities and also improve food security. Restoration and management of near shore ecosystems such as mangroves can reduce impacts of storm surges, decrease climate change vulnerability, and increase resilience. It is recognized that urban consumption patterns not only adversely impact nearby ecosystems but also ecosystems further away: urban teleconnections and the ecological footprint of cities are geographically dispersed and indeed immense. However, cities cannot be viewed as problematic merely because they form a large consumer base. They also hold the key to changing production and resource used by decreasing waste production, increasing recycling, and moving citizens to more sustainable forms of consumption. Furthermore, energy-efficient and renewable-energy infrastructure development through economies of scale can reduce emissions. Ecological infrastructure in cities regulates local temperatures and buffers the effects of urban heat islands. For example,

water areas buffer temperature extremes by absorbing heat in summertime and by releasing it in wintertime (Chaparro and Terradas, 2009). Likewise, vegetation reduces temperature in the hottest months through shading and through absorbing heat from the air by evapotranspiration, particularly, when humidity is low (Hardin and Jensen, 2007). Water from the plants absorbs heat as it evaporates, thus cooling the air in the process (Nowak and Crane, 2000). Trees can also regulate local surface and air temperatures by reflecting solar radiation and shading surfaces, such as streets and sidewalks that would otherwise absorb heat. Decreasing the heat loading of the city is among the most important regulating ecosystem services trees provided to cities (McPhearson, 2011).

Technological improvements, which enhance longevity of life through medical advancement has contributed to the continued increase in population. The population structure of most developing countries is broad based, meaning there are more young people who are likely to migrate to the area of opportunities hereby increasing the population of these areas. The demand and increase in car ownership and improvement in the public transport system enable both low and high income earners to move from their work places in the city centre to the periphery. Distance to a large degree no longer inhibits the decision to reside at the periphery. It has been observed that with the improvement in mass transport system low income groups could also afford to commute to and from the peri-urban areas. In cities like Kaduna, peripheral areas grow at a very fast rate along major transportation corridors, highways and railway lines. This has brought about the growth of settlements like Jere, Katari, Rijana and Tafa amongst others along the Kaduna-Abuja Expressway. Similarly, settlement like Rigasa is witnessing rapid growth with the completion of the Abuja-Kaduna standard gauge railway project which is currently in operation has gone a long in easing the movement of people goods and services to and from the two areas as most people opts for the railway transportation as against the road with attendant security challenges like arm robbery and kidnapping.

Carpooling and carsharing service or urban lift-sharing services which involves the sharing of car journeys so that more than one person travels in a car by matching services that bring people together who are travelling in the same direction to share private vehicles for particular journeys. Similarly, carsharing involves short-term automobile rental services intended to substitute for private vehicle ownership and making an affordable and occasional use of a vehicle: several users share the access to a car fleet, which is owned and managed by a service provider. They use advanced technologies (e.g. matching software, the internet and optional call centres) for trip matching, increasing the potential to reach critical mass of users. Carpooling and carsharing reduces each person's travel costs such as fuel costs, tolls, reduces

congestion, pollution, demand for parking and even the stress of driving; it is also seen as a more environmentally friendly and sustainable way to travel.

Kaduna is one of the biggest cities in Nigeria that is perennially plagued by traffic gridlocks that could last hours on end. Carpooling or ride-sharing is undoubtedly the key to easing the already critical traffic situation which would give back to commuters, the hours of manpower and productivity that are lost to traffic each day. Though, elements of carpooling and ridesharing exist in most motor parks in Kaduna metropolis and Nigeria in general, but the mode of operation and the timely availability of these rides have failed to achieve the desired results simply due to inconveniences and delays inherent in the present system. However, with burgeoning technology, with more and more people utilizing and engaging technology several platforms like Uber and NG-Ride bookings emerging to boost carpooling and ridesharing services. Not only is technology a smart use of resources, it is the future of transportation in Nigeria. Nevertheless cities are buying more energy efficient cars to curb carbon emissions, new transport trends have now become an important ally in that regard.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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