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Exploring the Influence of Street Network on Commute Well-Being in Abuja City, Nigeria

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Abstract
Improvement of street network to ensure well-being in cities has become a global concern in the recent years. Tremendous efforts have been made to determine the influence of urban road network on societal well-being. However, well-being has usually been evaluated by considering objective influence of transportation system. The subjective or personal well-being of transport network is scarcely explored in developing world cities. This study therefore evaluates the connection of street network in Abuja city. It also measures personal well-being; individuals' satisfaction with different indicators of commute well-being, overall enhancement in lifestyle and compares satisfaction with commute well-being between the city districts. Results indicate that majority (60%) of the districts in Abuja city have low street connectivity. About 22.5% of the districts have moderate street connectivity. Only 17.5% districts, mainly those located at the inner-city have high street connectivity. Results also reveal that there are differences in satisfaction with commute well-being among the districts. The Post-hoc result shows a statistically significant difference in well-being between low and high connected districts, suggesting that there is more satisfaction and commute well-being in the high connected districts than in the less connected districts of Abuja city. The outcome of this study implies that it is necessary and imperative to focus and intensify effort towards developing more road network in the districts with very low street connections so as to curtail regional imbalance. Such will not only ensure good environment, but also control traffic speed, reduce delay in public transportation, improve journey time and local economy. Consequently, this will safeguard commute well-being and social equity among the entire dwellers of Abuja city.

Keywords: Street Network, Commute Well-Being, Abuja City

Introduction

Well-being is a multidimensional perception that could be measured both objectively and subjectively. In transport, well-being has more frequently been evaluated by considering objective influences of transport system such as travel times and costs, crashes, and environmental degradation. However, the subjective knowledge of transport, such as how it adds to overall satisfaction, is recently of growing concern (Mokhtarian, 2019). Subjective wellbeing (SWB) considers wellbeing as perceived by individuals based on the view that "people are the best judges of how their life is going" (OECD, 2011, p. 265).

There is no specific universally adapted definition of well-being. It is formally defined as "Good mental states, including all of the various evaluations, positive and negative, that people make of their lives, and the affective reactions of people to their experiences" (OECD, 2013, p. 10). Well-being is also defined as "the state of being happy, healthy and successful (MerriamWebster, n.d). In other words, well-being refers to public satisfaction with tangible and intangible materials such as movement which emerged within the Social Indicators Movement and questions basic assumptions about the link between comfort and the complex nature of individual and social material and immaterial well-being (Myers, 1988).

Internal perception and judgement of life satisfaction is established on the assumption that people's experiential comfort is best examined by direct expression of their personal feelings about conditions of life (Diener and Suh, 1997; Das, 2008). The concept of well-being does not rely on the conviction of decision-makers, scholars, or others. This makes the approach superior, suitable and more preferred means of exploring personal well-being (Lee 2008; Ibrahim and Chung 2003). According to Tinkler & Hicks (2011), well-being can be measured by determining evaluative well-being – how satisfied individuals are with diverse spheres of their life and with life overall; and experiential wellbeing – how often people experience positive and negative emotion. Well-being in commute domain has influence on overall human well-being. For example, people may experience pleasure and enjoyment just going for a walk or bicycle ride. Secondly, enhancement in travel conditions may increase choices to participate in significant or pleasant activities and may lessen stress linked with these activities, thereby increasing well-being (Pychl and Little, 1998).

Street network denotes a system of roads with various routes and connections serving the same origins and destinations. It does not only relate to the number of intersections along a segment of street, but how the entire area is connected by the transportation system (Dam et al., 2011). A good street network is indispensable for sustainable and enhanced well-being in cities, as it ensures a viable development (Thales, 2012 and Sreelekha et al., 2016b). It is good for ecological environment, it controls traffic speeds, reduces delay in public transportation, improves journey time, and beneficial for the local economy (Wade & Sommers, 2006). An increasing body of research suggests that residential neighborhood density and street connectivity affect walking and total physical activity (Oakes, et al, 2007). Despite its importance for societal well-being, scarce attempts have been made in the field of transportation to devise a concrete mechanism for classifying road network into the levels of connectivity. This makes it difficult to contrast road connection pattern between distinct regions.

The relationship between well-being and transportation has recently attracted much attention from scholars globally. Investigating the link between road network and commute well-being started in recent times. As a result, literature on the influence of street network on personal comfort and public transport is limited (Delbosc, 2012; Chng et al., 2016). The social impact of transport network has not been sufficiently explored particularly in developing country cities (Tiwari and Arora, 2012). Equally, it is acknowledged that the influence of transport network on urban lifestyle has been overlooked in research community (Mohamed et al., 2013). There is also limited studies that consider relationships between commute mode and well-being focused on whether certain modes are associated with positive well-being such as life satisfaction (Stutzer and Frey, 2008; Schneider, 2013). Generally, the influence of road network on individual commute well-being is scarcely explored. Hence, there is little knowledge on how transport network generally contributes to human well-being. This limits the ability to make effective transport policies that improves subjective well-being. Therefore, this study investigated three key questions: One, is street network adequately distributed among the people living in all the districts. Two, are individuals likely to have the same level of satisfaction with the various commute well-being indicators. Three, is well-being higher among individuals living in the districts with good street connectivity. This study will proffer a better understanding of street network influence on commute well-being. The outcome will also help in designing transport and urban planning policies and interventions that improve social well-being in cities and elsewhere.

Materials and Method

This research was conducted in Abuja city which is located in the middle of Nigeria (Figure 1) at Latitude 7° 25' N & 9° 20' N of the Equator and Longitude 5° 45' E & 7 39' E of the Greenwich Meridian. The Federal Capital Territory (FCT) has a land mass coverage of 2,824 Square Miles (7,315 Km^2) (Dawan, 2000). About six local area councils constitute the FCT, including Abaji, Abuja Municipality, Bwari, Gwagwalada, Kuje, and Kwali (Figure1). Abuja city is situated in the Metropolitan area council and covers a land area of 250 Km^2. The metropolis has a total road length of 1,738.95 Kilometres. The paved roads have a total length of 1,028.8 Kilometres while the unpaved roads cover a distance of 710.15 Kilometres.

Graph theoretical technique was adopted to determine the pattern of street connections in Abuja city. The total length of road, links (edges) and number of nodes (vertices) estimated in each district were used to compute graph theory properties (indices) of street connectivity using the formula outlined in Table 1. Each of these indices represent various elements in determining street network characteristics.

Table 1: Graph Theory Indices Used in Determining Street Network Characteristics

Graph Theory Index	Formula	Significance
Alpha Index	$\alpha = \frac{\upsilon}{2\nu-5}$	Evaluates the number of cycles in comparison with the maximum number of cycles in network.
Beta Index	$\beta = \frac{e}{V}$	Measures the level of connectivity in transport network or graph.
Cyclomatic Number	$\cup = e - v + 1$	Determines quantity of arcs or links that form tree in transport network.
Eta Index	$\eta = \frac{L(G)}{e}$	Examines the utility of a transport network.
Gamma index	$\gamma = \frac{e}{3(V-2)}$	Determines the ratio of observed links to the number of possible links in transport network.
Aggregate Transportation Score	$ATS = \beta + \cap + \gamma + \alpha + \cup$	Defines the overall connectivity in a given transport network.

Quotient model was applied to classify the Aggregate Transportation Score values into three (low, moderate and high) levels of road connectivity districts. Quotient model is a means of determining equivalence ratio by partitioning a set of values into upper, middle and lower equivalent classes (Dubois and Prade, 1992, Yao and She, 2016). The formula used for this calculation is as follows:

$$Qt = \frac{Dividend}{Divisor}$$

Weighting approach, also known as weighted average score (GUK, 2015) was used to determine the average significance of preferential choices made by respondents' observation in a satisfaction survey. The weighting figures (Strongly disagree = 1, disagree = 2, neutral = 3, agree = 4, strongly agree = 5) were assigned to the respective answer choices. The weighted average score was calculated for commuters' satisfaction in each of the fifteen selected case study districts. After which the weighted average score of the measuring items were summed up to denote the value of their respective satisfaction indicators. The mean scores were further calculated for all satisfaction indicators to connote the overall score for every set of districts in the three (high, moderate and low) connectivity categories. These scores were used to estimate the internal or emotional satisfaction with the various measuring items of commuters. The generated data were used for comparing commute well-being between the sampled districts. The formula (Kartalopoulos, 2006, Pretorius et al., 2017) and steps involved in the calculation were as follows:

Step 1: Formula: $X = \frac{\Sigma Fx}{N}$

Where:
X = the weighted average score,
F = the frequency,
x = the weight of each item,
N = the number of cases (i.e responses) in a district.

Step 2: The weighted average score of the measuring items were summed up for each district to represent the value of their respective commute satisfaction indicators.

Step 3: The mean scores were calculated for the respective commute satisfaction indicators to denote the overall score of the districts which constitute each of the three categories of street connectivity.

Finally, Analysis of variance (ANOVA) test statistics was used to compare commute well-being among the three categories of street connectivity in Abuja city. Subsequent are the steps followed in computing ANOVA:

- First step was computation of total sum of the squares.
- Second stage was calculation of squares between columns.
- Third stage was computing sum of squares within the column.
- Fourth stage was to create ANOVA table and calculating the mean sum of squares.
- Finally, post-hocs multiple comparisons was performed to test the exact dissimilarities existing between the individual groups.

To obtain the required data, five (5) case study districts from each of the three connectivity categories were sampled for assessment. Overall, fifteen (37.5%) out of the forty districts within Abuja municipality were sampled in which 388 questionnaires were distributed to the respondents. At last, 367 surveys were found valid, and coded for the study. An intensive literature review was carried out to identify commute well-being indicators. Questionnaire was designed to guide the respondents in grading their satisfaction with the identified commute well-being indicators.

Results and Discussion

This research was intended to compare commuters' satisfaction with transport-related well-being indicators between the districts with different categories of street connectivity. Results of the finding are discussed in this section as follows.

Street Connectivity

Aggregate Transportation Scores (ATS) was used to measure the connectivity in each district in order to ascertain the sorts of street connection in the city. The Aggregate Transportation Scores in Table 2 shows that the districts in Abuja city are categorized into three (high, moderate and low) street connectivity.

Table 2: Aggregate Transportation Score of Street Connectivity in Abuja City

Classification	ATS	Districts	Number of Districts	Percentage
Lower Street Connectivity	6.66 – 48.71	Apo (23.83), Dakibiu (14.09), Dape (6.66), Duboyi (13.62), Durumi (17.94), Dutse (24.93), Gaduwa (16.85), Kabusa (11.92) Kafe (22.91), Katampe (15.87), Kaura (11.66), Kukwaba (21.31), Mabushi (15.06), Salini (11.17), Wumba (22.89), Wupa (30.99) Guzape (35.23), Gwarimpa 1 (43.88), Gwarimpa 2 (31.00), Jabi (35.15), Jahi (34.11), Kado (34.11), Karimo (37.08), Utako (46.23)	24	60%
Moderate Street Connectivity	50 – 97.42	Dakwo (51.04), Wuye (54.31) Galadima (79), Garki 1 (76.70), Garki 2 (74.85), Gudu (61.96), Bunkoro (91.00), Wuse 2 (76.98) Nbora (83.08)	9	22.5%
Higher Street Connectivity	98 – 146.13	Asokoro (100.98), City Centre (103.04), Indstrl A. 2, (115.07), Instns & Rsch A. (109.07) Lokogoma (117.92), Maitama (109.84), Wuse 1 (146.13)	7	17.5%
	Total		40	100%

The result in Table 2 reveals that majority 24 (60%) of districts in Abuja city, particularly those situated at the periphery have low street connectivity. About 9 (22.5%) of the districts have moderate street connectivity. Only 7 (17.5%) districts, mostly those located at the inner-city

(Wuse 1, Maitama, City-Centre and Asokoro) have high street connectivity. This result suggests that most of the districts in Abuja metropolis have low street connectivity. The implication is that walking, cycling and total physical activity are seriously affected. Directness of travel is also disturbed, making travel more or less efficient, and the number of alternative routes with implications for interest and safety. Although, high street connectivity may also discourage physical activity participation in children and youth.

Satisfaction with Commute Well-Being Indicators

In this study, seven travel well-being indicators were surveyed. These included personal mobility, personal accessibility, travel safety, travel comfort, economic well-being and social interaction. The significance of preferential choices made by respondents' observation on the mentioned indicators in each district was determined using weighted average score as presented in Table 3.

The results indicate that among the low connected districts, Utako district has the highest (23.25) while Katampe district has the lowermost (17.30) factors average. This implies that the inhabitants of Utako have higher commute well-being, and those in Katampe district have lesser commute well – being in the low connected districts. In the moderate connected districts, Galadima has the highest (23.94) and Wuye has the smallest (18.11) factors average. This denotes that the people living in Galadima have better, while those in Wuye have little commute well-being among the moderately connected districts of Abuja metropolis. In the high connected districts, Lokogoma has the highest (22.56) while Wuse 1 has the smallest (20.92) factors average. This suggests that Lokogoma has improved commute well-being whereas Wuse 1 has the least commute well-being. Overall, Galadima has the uppermost (23.94) while Katampe has the least (17.30) factors average; inferring that commute well-being is higher in Galadima district and lesser in Katampe district in the entire Abuja metropolis. Improved commute well-being is associated with higher job and leisure time satisfaction, decreased strain and better mental health and vise-viser.

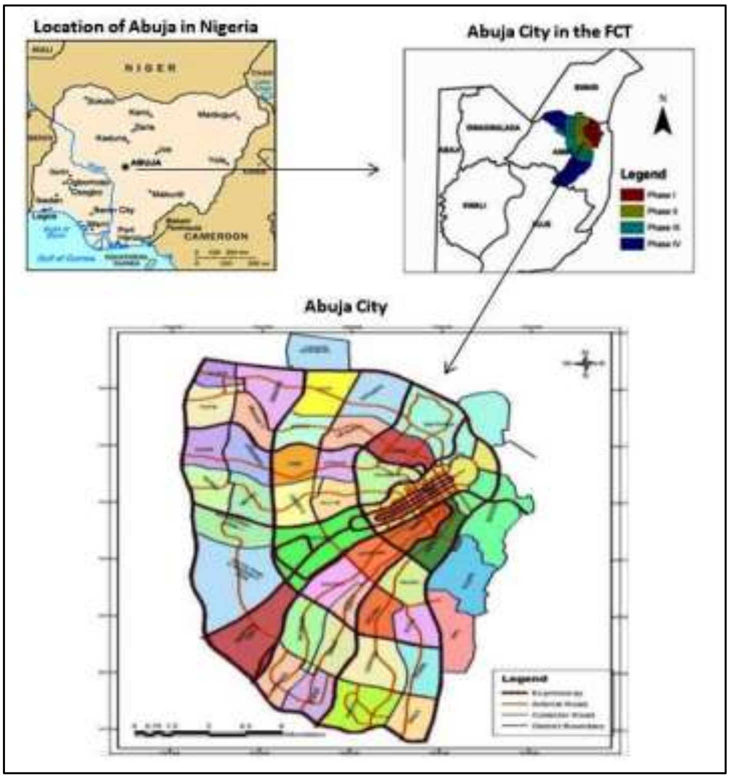

Figure 1: Study Area

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Table 3: District-Wise Commute Satisfaction Weighted Average (Score)

	Low Street Connectivity Districts					Moderate Street Connectivity Districts					High Street Connectivity Districts				
Commute Well-Being Indicator	**Apo**	**Durumi**	**Gwarimpa 1**	**Katampe**	**Utako**	**Bunkoro**	**Galadima**	**Gudu**	**Nbora**	**Wuye**	**Asokoro**	**City Centre**	**Lokogoma**	**Maitama**	**Wuse 1**
Personal Mobility	16.11	17.22	18.65	15.18	19.36	19.2	20.17	18.88	14.47	16.01	18.69	18.7	17.73	19.23	17.58
Personal Access	16.09	15.74	12.21	14.22	23.0	19.93	20.83	19.07	15.77	14.63	17.68	19.66	17.91	19.79	18.15
Travel Safety	17.52	22.77	19.33	20.01	14.64	23.83	24.18	22.5	21.58	21.82	22.92	22.07	22.46	20.82	20.43
Travel Comfort	16.89	17.0	16.41	15.05	19.64	20.04	24.34	21.45	13.92	14.27	21.68	21.38	21.2	19.98	19.34
Eco-Well being	20.32	20.4	19.51	15.95	26.0	26.16	23.99	23.25	19.94	19.01	23.8	21.73	25.36	22.49	20.2
Social Interaction	26.22	24.92	25.03	23.41	36.88	32.82	30.15	30.38	23.17	22.93	25.7	30.21	30.72	31.58	29.84
Factors Average	**18.86**	**19.68**	**18.52**	**17.30**	**23.25**	**23.66**	**23.94**	**22.59**	**18.14**	**18.11**	**21.75**	**22.29**	**22.56**	**22.32**	**20.92**

Comparison of Commute Well-being between the Three Groups of Street Connectivity

The result of one-way ANOVA is presented in Table 4. It indicates a statistically significant difference in commute satisfaction at < .05 level for the three categories of street connectivity: *F* (2, 12) = 3.93, *p* = 0.49. However, it is yet uncertain which of the specific groups differ.

Table 4: Commute Well-being Analysis of Variance (ANOVA)

ANOVA
Commute Satisfaction

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	26.548	2	13.274	3.927	.049
Within Groups	40.564	12	3.380		
Total	67.112	14			

The actual difference in satisfaction with commute well-being indicators was determined using Turkey post hoc test as illustrated in Table 5. The result shows a statistically significant difference in well-being between the low connected districts (*M* = 18.87, *SD* = 1.06) and the high connected districts (*M* = 21.97, *SD* = 0.66, *p* = 0.05). However, no significant variance exists between moderate connected districts (*M* = 21.29, *SD* = 2.93, *p* = 0.14) and low connected districts, likewise between the moderate connected districts and high connected districts (*p* = 0.83). The significant difference (*p* = 0.050) in well-being between low connected districts and high connected districts suggests that there is more satisfaction and commute well-being in the connected districts than in the less connected districts.

Table 5: Result of Post Hoc Tests

Multiple Comparisons

Dependent Variable: Commute Satisfaction
Tukey HSD

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Low	Moderate	-2.42000	1.16281	.136	-5.5222	.6822
	High	-3.10000	1.16281	.050	-6.2022	.0022
Moderate	Low	2.42000	1.16281	.136	-.6822	5.5222
	High	-.68000	1.16281	.831	-3.7822	2.4222
High	Low	3.10000	1.16281	.050	-.0022	6.2022
	Moderate	.68000	1.16281	.831	-2.4222	3.7822

Conclusion

This study has unveiled the characteristics of street connection and personal satisfaction with commute well-being in Abuja city. It has revealed that 60% of districts in Abuja city, particularly those situated at the periphery have low street connectivity. About 22.5% of the districts have moderate street connectivity, while only 17.5% districts, mostly those located at the inner-city have high street connectivity. The significance of preferential choices made by respondents' observation on the indicators in their respective districts discovered that Utako district has the highest (23.25) weighted average score in the lowermost connected districts, Galadima has the highest (23.94) in the moderately, while Lokogoma has the highest (22.56) in the highly connected districts of the city. Result of post hoc test showed more *(p* = 0.05) satisfaction and commute well-being in the connected districts than in the less connected districts. This implies that it is necessary and imperative to focus and intensify effort towards developing more road network in the districts with very low street connections so as to curtail regional imbalance. Such will not only ensure good environment, but also control traffic speed, reduce delay in public transportation, improve journey time and local economy. Consequently, this will ensure commute well-being and social equity among the entire dwellers of Abuja city and elsewhere.

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