Ground Truthing: Perceived Versus Objectively Measured Built Environment Attributes in South African Communities

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Abstract
No ground truthing study of ‘neighbourhood walkability’ has been conducted in Africa that contrasts the lived experience of the neighbourhood-built environment against objectively measured attributes using GIS and subscales of the NEWS-Africa instrument.

Methods: This is a cross-sectional survey and observation study. A convenient sample of residents (n=52) aged 18-65 years from four urban suburbs in low- and high-income settings, self-reported transport, leisure-time physical activity (PA) and device-measured moderate-to-vigorous PA (MVPA) were assessed. Built environment constructs was derived from individual-level street network measures (1000m buffer, using ArcGIS 10.51). We also assessed PA between the four groups based on income and GIS walkability.

Results: There was no significant relationship between self-reported MVPA and GIS-measured walkability in the study sample. Only intersection density had a significant inversely association with moderate and MVPA (rho=-0.31, P<0.05) in the overall study sample. Self-report transport PA differed between groups (P<0.013). Device-measured vigorous activity differed between groups and was lower in both Low-SES groups compared to the High-SES/Low Walkable group (P<0.04). Total PA was not associated with GIS measured walkability, but inversely associated with positive perceived neighbourhood attributes.

Conclusions: There is a modest inverse association between device-measured PA and GIS-measured intersection density. These results suggest that constructs of walkability, whether measured or perceived, may predict volitional and utilitarian PA differently in our study population.

Keywords: Physical activity, built environment, walkability, transportation, ground-truthing.
1.0 Introduction

Many studies have underscored the relationship between supportive attributes of the built environment and physical activity undertaken for transportation or recreation (1–5), but most of the evidence is from high-income countries. In Africa, studies of the built environment and physical activity relationships remain scarce (6). One of the tools for measuring walkability, the Neighbourhood Environmental Walkability Scale (NEWS), is perhaps the most widely used instrument. It is used to assess perceptions of the neighbourhood built and social environment, concerning physical activity (7). In a collaborative effort by a group of health and physical activity researchers in Africa and the University of San Diego, USA, the NEWS was subsequently adapted, in an effort to make it more compatible for use in communities and cities from the African continent (8). The adaption and evaluation the NEWS was carried out in seven sub-Saharan African countries across the East (Kenya, Uganda), West (Ghana, Nigeria), Central (Cameroon) and Southern (South Africa and Mozambique,) Africa.

Measures of reliability and validity of the NEWS-Africa tool were then carried out (8). However, one of the limitations of the NEWS-Africa study was that it relied entirely on self-reported physical activity as the measure to determine construct validity. These measures are prone to bias, recall problems and inaccuracy of measurement (8), especially of physical activity and intensities. Furthermore, they failed to compare high- and low- walkable communities and high- and low- income settings (8). The studies also failed to provide the criterion validity using device-measured physical activity or objective measures of built environment attributes. The authors highlighted the need to explore the construct and predictive validity in future studies. Ground-truthing studies using GIS regarding actual distances to amenities, traffic and crime were also proposed to provide additional insights into the factors related to the perceived environment which would potentially impact on physical activity.

Ground-truthing involves a systematic and direct observation of various attributes of the built environment. In the case of physical activity, this may include road networks, land use, destinations, aesthetics, recreational facilities and sporting venues, community centres and shopping destinations, traffic safety, and lighting (9). To our knowledge, a "ground truthing" study of neighbourhood "walkability" has not been conducted in Africa that contrasts the "lived experience" of the neighbourhood-built environment against objectively-measured attributes and to identify the factors that shape any inconsistencies in these measures and addresses issues of environmental justice. South Africa, as a nation has vast inequalities (high GINI coefficient) and therefore ground-truthing the built environment in relation to incidental, utilitarian, and leisure-time physical activity, may provide insights to better understand the ecological and environmental barriers to participation in physical activity, to address issues of social justice.

A recent ground-truthing study concerning the six attributes of neighbourhood walkability was conducted in 14 countries from the IPEN network, including cities in New Zealand, Hong Kong, China, and several European cities, Mexico City, Brazil, Colombia and the United States (9). This multi-country study identified urban environmental attributes that accounted for significant differences in physical activity, including net residential density, public transport density and park density (9).
This combination of environmental features generally explained more variation in physical activity than individual variables, such as intersection density, suggesting that comprehensive approaches were needed to design physical activity-supportive neighbourhoods.

One of the recommendations from the aforementioned study was to expand the research to low-income countries in which associations between urban environment and physical activity have not been previously assessed. Also, the authors had indicated the need to develop objective measures for environmental attributes relevant to physical activity like sidewalks, pedestrian zones, bicycle facilities and factors affecting intersection quality such as: crosswalks, pedestrian signals and traffic calming (9).

Taking the above recommendations into consideration, this study aimed to: 1) examine walkability constructs and subscales of the NEWS-Africa instrument, utilising ground-truthing and remote-sensing technology (Geographic Information Systems, GIS) in an urban South African setting; and 2) examine the extent to which socioeconomic status of communities influences these associations.

2.0 Materials and Methods

2.1 Study Design

This is a cross-sectional survey and observation study.

2.2 Study setting and sample size

This study was conducted in four urban suburbs in Cape Town (See Figure 1). This study involved a convenience sample of 66 adults, for which 52 participants had complete data (Pinelands = 13, Table View = 13, Khayelitsha =12, Langa =14). The remainder partly complete data and 10 of the initial participants moved to another area during the study and another 4 had incomplete. In our sample (n=52), 10 were men and 42 were women, and were regular members of either church or community groups in these four suburbs.

The study population comprised adults between ages 18 and 65 years residing in their place of residence for at least three months. Within this age group, individuals were eligible for inclusion irrespective of their religious affiliation, employer, type or grade of occupation, literacy level, length of employment contract, type of employment contract (full or part-time contract) and whether they worked in other locations.

2.3 The NEWS Africa Tool

The Neighbourhood Environment Walkability Scale (NEWS) is perhaps the most widely used instrument to examine the perceptions of the neighbourhood built and social environment concerning physical activity (10). This instrument has been used since 1997 in single or multi-country studies to understand the correlates of the built environment and physical activity (8). In a collaborative effort by a group of health and physical activity researchers in Africa and the University of San Diego in the USA, the NEWS was subsequently adapted to make it more compatible for use in the African settings (8). The adaption and evaluation the NEWS was carried out in seven sub-Saharan African countries across the East (Kenya, Uganda), West (Ghana, Nigeria), Central (Cameroon) and Southern Africa (Mozambique, Republic of South Africa).
The final NEWS-Africa survey produced through this process had 76 individual items and 13 subscales that assessed the following environmental characteristics: *Types of residences* (6 items). *Destinations scale* (27 items). *Recreation scale* (4 items). * Roads and walking paths scales* (5 items). *Sidewalk scale* (5 items). *Crossing paths scale* (4 items). *Paths infrastructure scale* (2 items). *Places for walking, cycling, and playing overall scale* (12 items). *Neighbourhood surroundings scale* (8 items). *Safety from Traffic scale* (6 items). *Safety from Crime scale* (4 items). *Personal safety scale* (3 items). * Stranger danger scale* (3 items). The News tool has been found to be reliable (11) and valid (2) for Africa settings.

In our study we utilised the *Destinations scale* i.e., proximity to non-residential (land uses - land use mix - diversity), and ease of access to non-residential uses (land use mix - access). We identified 6 of the 27 items of Destinations scale (mainly, the perceived distances in minutes of walking on an ordinal scale) and compared them with measures determined by GIS that is: i) Health Clinics vs. Hospitals; ii) Places of worship vs. Faith centres; iii) Workplaces or Schools vs Nearest work place/school; iv) Sports fields vs. Courts vs Nearest sports ground; v) Public bus or train stops vs. Closest transport and; vi) Other indoor recreation facilities vs Nearest recreational hub.

### 2.4 Geographic Information Systems (GIS)

#### Buffer size and type:  Using Geographic Information Systems (GIS) (ArcGIS version 10.51), we identified the available physical activity facilities which included sporting venues, recreational centres, and parks within each residential buffer. The source of the point data was the City of Cape Town 2011 census. Radial buffers (500m, 1000m and 1600m) were established (12) around the street intersection closest to each participant’s home address, at distances that corresponded to 5-7 min (500m), 10-12 min (1000m) and 15-18 (1600m) minutes walking time for persons traveling on foot. The methodology used was based on Adams et al. (9), who employed the individual-level street network buffer-based GIS measures. The advantage of using this approach was to assess the participants within the neighbourhood and captured destinations that participants could access from the road network. As a result, this method has merits compared to an administrative boundary approach of defining neighbourhoods (9).

### 2.5 Walkability measures using GIS

Walkability is measured using an index termed walkability index and the four components include. Net residential density, Retail floor ratio, Intersection density and Land use mix(13); Net residential density: the ratio of residential units to land area that is devoted to residential use per block group. Retail floor area ratio: retail building floor area footprint divided by retail floor area footprint. It is assumed that low ratio indicated a retail development likely to have a substantial parking, while a high ratio indicated smaller setbacks and less surface parking – the two main factors that enabled pedestrian access. Intersection density is the connectivity of the street network, represented by the ratio between the number of true intersections (three or more legs) to the area of block groups in acres. A higher density of intersections corresponds with a more direct path between destinations. Land use mix or entropy score indicated a degree to which diversity of land use types were present in a block group. These four calculated values are normalised using a Z score. An example would be a normalised net residential density score of “1” suggests that the raw value is 1 and the standard deviation above the mean value of the category.
The walkability index in this study was computed as the sum of Z scores for net residential density, land use mix and diversity, and intersection density (9). The walkability index was adapted from (13) Frank et al., 2010 (13) and calculated as:

\[
\text{Walkability} = (2 \times z_{\text{intersection density}} + z_{\text{net residential density}} + z_{\text{retail floor area}} + z_{\text{land use mix}}).
\]

**Figure 1: An overview of Intersection density in the four study suburbs**

2.5.1 Measuring components walkability in this study:

**Net Residential Density**

Net residential density was computed as the number of dwellings (numerator) divided by the land area dedicated to residential use, within the three buffers (13). The residential density was computed for each buffer in each of the suburbs ((dwelling count/residential area) *1,000,000).
Street connectivity
Street connectivity was operationalised as intersection density (9). This was defined as the ratio of the number of intersections within each participant's buffer (numerator) divided by the total buffer area. Previous papers (13,14) have established intersection density as a measure of route directness, which captures the ability to move to and from destinations in a direct pathway.

The intersection density
An intersection in this study was defined as a point where three or more segments intersected after removal of limited access roads and pseudo intersection nodes (9). All streets in Cape Town were merged and cut out to fit the buffers in the four suburbs, the street connections were then set to point, and the points were joined in the buffers and aggregated to get each intersection in all the buffers. The intersection density was computed as \( \frac{(\text{intersection count}/\text{buffer area}) \times 1,000,000} {\text{buffer area}} \).

Land-use Mix and Diversity
Four land uses were computed: residential, retail-combined, civic/institutional and others. Parcel data was used to quantify the land uses. Land-use mix was calculated using an entropy equation (15) to score the area based on these four land use types (9).

<table>
<thead>
<tr>
<th>Neighbourhood</th>
<th>Land area of community (km²)</th>
<th>Population density (persons/Km²)</th>
<th>Land-use types</th>
<th>Residential % Mean (SD)</th>
<th>Retail combined % Mean (SD)</th>
<th>Civic % Mean SD</th>
<th>Other Mean (SD)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Khayelitsha</td>
<td>38.70</td>
<td>10,120</td>
<td></td>
<td>18.8 (7.5)</td>
<td>1.7 (1.6)</td>
<td>8.0 (4.2)</td>
<td>71.5 (12.3)</td>
</tr>
<tr>
<td>Langa</td>
<td>3.09</td>
<td>16,958</td>
<td></td>
<td>32.7 (5.0)</td>
<td>5.2 (2.8)</td>
<td>12.1 (2.4)</td>
<td>50.0 (8.6)</td>
</tr>
<tr>
<td>Table view</td>
<td>6.14</td>
<td>2,800</td>
<td></td>
<td>57.8 (16.0)</td>
<td>5.1 (3.0)</td>
<td>15.8 (6.4)</td>
<td>21.3 (15.7)</td>
</tr>
<tr>
<td>Pinelands</td>
<td>5.86</td>
<td>2,400</td>
<td></td>
<td>54.1 (7.6)</td>
<td>4.4 (4.1)</td>
<td>11.3 (3.3)</td>
<td>30.1 (7.7)</td>
</tr>
</tbody>
</table>

The area of the four land uses was summed up and later divided by each land use to get the proportion of land use for each buffer (land use ÷ sum of land use types) ×100 (See Table 1). Table one gives the Land-use mix diversity of the four suburbs.

Public Transport density
For this study, all bus stops, integrated rapid transit system stops, and railway stops were documented in each buffer zone. Public transport density was computed as the number of public transport stops divided by buffer area (transport stops ÷ transport zones) ×1,000,000 (16).
3.0 Analyses
We correlated the perceived distances (in minutes of walking on an ordinal scale) between the NEWS-Africa survey (6 items from the Destinations scale) for: i) places of worship/faith centres; ii) workplaces or schools, health clinics/hospitals, Sports fields/Courts/Other outdoor recreation spaces, Public bus or train stops/Closest transport, against those same measures determined using GIS.

We used Spearman’s rho rank order correlations for selected NEWS-Africa scales vs geocoded variables. We also correlated the parameters that comprised the GIS measured walkability index against the perceived attributes of the built environment (NEWS-Africa subscales) in the (1000m buffer). The sample was divided into four groups using a median split using the GIS-measured walkability index (Low-SES/Low walkable, High-SES/ Low walkable, Low-SES/High walkable, High-SES/High walkable). Perceived neighbourhood variables (including estimated walking distances or proximity to destinations, and the various walkability subscales), were compared between groups using Kruskal-Wallis non-parametric ANOVA. All data were analysed using Statistica (Stat Soft ® 2014 version 13 for Windows (IBM Corp: New York).

4.0 Ethics considerations
This research study was approved by the University of Cape Town Health Sciences Research Ethics committee (HREC REF 293/2016). Participation in the study was voluntarily, and participants were consented when they have given a verbal or written consent.

5.0 Results
Tables 2 shows the percentage contribution of the various components of Land Use Mix, including residential, retail, civic and other (which is poorly defined and, in some cases, includes public open space, green space, blocked roads and special zones for subdivisions or future development) across the 4 communities. In the two high-SES neighbourhoods, residential land use was significantly higher than in the low-SES communities, despite a much higher population density in these communities, whereas unspecified use was higher in the low-SES groups. Table 3 shows the median (and 25th and 75th percentiles) of GIS variables of the construct of walkability (Land Use Mix, Residential Density, Intersection Density) and Transport density for the two combined SES groups. We demonstrated that Intersection density (p=0.04) and Residential density (p=0.001) were significantly higher in the low-SES areas combined to the high-SES neighbourhoods. (P= 0.04).

<table>
<thead>
<tr>
<th>Table 2. Components of Land Use Mix by Low- and High SES groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>Components of Land Use</td>
</tr>
<tr>
<td>------------------------</td>
</tr>
<tr>
<td>Residential (%)</td>
</tr>
<tr>
<td>Retail combined (%)</td>
</tr>
<tr>
<td>Civic (%)</td>
</tr>
</tbody>
</table>
Table 3: GIS measures of walkability and Transport Hub density between low- and high-SES groups

<table>
<thead>
<tr>
<th>GIS variables</th>
<th>Low SES</th>
<th>High SES</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land-use mix (0-1)</td>
<td>25</td>
<td>26</td>
<td>0.15</td>
</tr>
<tr>
<td>Median (25th; 75th centile)</td>
<td>0.9 (0.7; 1.0)</td>
<td>0.9 (0.9; 1.0)</td>
<td></td>
</tr>
<tr>
<td>Intersection Density (counts per m²)</td>
<td>25</td>
<td>26</td>
<td>0.04**</td>
</tr>
<tr>
<td>Median (25th; 75th centile)</td>
<td>53.8 (41.7; 74.5)</td>
<td>41.7 (36.9; 46.8)</td>
<td></td>
</tr>
<tr>
<td>Residential density (Units per m²)</td>
<td>25</td>
<td>26</td>
<td>0.001**</td>
</tr>
<tr>
<td>Median (25th; 75th centile)</td>
<td>3699.5 (2718.0; 4537.9)</td>
<td>715.2 (624.9; 1169.3)</td>
<td></td>
</tr>
<tr>
<td>Transport density (Units per m²)</td>
<td>25</td>
<td>26</td>
<td>0.11</td>
</tr>
<tr>
<td>Median (25th; 75th centile)</td>
<td>6.0 (0.3; 10.2)</td>
<td>7.3 (6.0; 12.7)</td>
<td></td>
</tr>
</tbody>
</table>

* Descriptive statistics for GIS device measured variables demographic variables using median lower and higher quartiles. Non-parametric comparison (Kruskal Wallis)/ and t-test to ascertain the significant difference.

5.1 Perceptions of proximity compared to objectively measured distances (Geocoded variables)
In table 4, we correlated the perceived distances (in minutes of walking on an ordinal scale) between the neighbourhood NEWS-Africa survey for: i) Health Clinics vs. Hospitals, ii) Places of worship vs. Faith centres, iii) Workplaces or Schools, Sports fields vs. Courts/Other outdoor recreation spaces; iv) Public bus or train stops vs. Closest transport to those same measures determined using GIS; and v) any Other indoor recreation facilities vs Nearest recreational hub. Participants living in high-SES neighbourhoods perceived sports fields and places of worship to be further away than they actually were ($r_s = -0.60, p=0.00$ and $r_s = -0.50, p=0.01$, respectively) and people in the low-SES and combined SES groups perceived Public bus/ train stop to be nearer than they actually were ($r_s = -0.50, p=0.00$).

Table 4: NEWS-Africa scales vs Geocoded variables

<table>
<thead>
<tr>
<th>NEWS Scales versus Geocoded Locations</th>
<th>Overall*</th>
<th>Low –SES</th>
<th>High- SES</th>
</tr>
</thead>
<tbody>
<tr>
<td>r coefficient</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Health clinic /Hospital vs Nearest Hospital</td>
<td>-0.2</td>
<td>0.3</td>
<td>-0.4</td>
</tr>
<tr>
<td>Place of worship /Faith centre vs Nearest worship</td>
<td>-0.3</td>
<td>0.0</td>
<td>-0.5**</td>
</tr>
<tr>
<td>Workplace/school vs Nearest workplace/ schools</td>
<td>0.0</td>
<td>-0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Sports field /court vs Nearest sports ground</td>
<td>-0.4**</td>
<td>-0.1</td>
<td>-0.6**</td>
</tr>
<tr>
<td>Public bus/ train stop vs Nearest Transport</td>
<td>-0.5**</td>
<td>-0.5**</td>
<td>-0.3</td>
</tr>
<tr>
<td>Other indoor recreation facilities vs Nearest recreational hub</td>
<td>-0.1</td>
<td>0.2</td>
<td>0.2</td>
</tr>
</tbody>
</table>

* Spearman’s rank order correlations for selected NEWS-Africa scales vs Geocoded variables. ** r-values are reported for comparisons that were statistically significant at p <0.05.
5.2 The relationship between the GIS measured walkability index parameters and the perceived built environment in the 1000m buffer

Table 5 shows the relationship between the parameters of GIS measured walkability index and the perceived attributes of the built environment (NEWS-Africa subscales) in the (1000 m buffers). Six of the 14 scales of the NEWS-Africa questionnaire were significantly correlated to GIS measured walkability index parameters in the low-, high – and combined-

In the overall sample, 5 scales were significantly correlated with GIS measured walkability index parameters. These included The Roads and walking paths scale, Places for walking, cycling playing (overall mean), Neighbourhood surroundings scale, Safety from Crime scale, Personal safety scale, Stranger danger scale.

The Roads and walking paths scale \( (r_s = 0.3, p=0.04) \) scale \( (r_s = 0.3, p=0.01) \) was positively associated with the GIS-measured walkability parameter Intersection density. When we considered GIS-measured Land use mix, 3 of the NEWS –Africa scales were correlated (The scales including Places for walking, cycling, and playing overall scale \( (r_s = 0.3, p=0.02) \), and Neighbourhood surroundings \( (r_s = 0.3, p=0.01) \), were positively associated, respectively). Conversely, Stranger danger was inversely correlated \( (r_s = -0.6, p=0.00) \).

Table 5: Correlations of GIS measured walkability index parameters and the perceived built environment in 1000m*

<table>
<thead>
<tr>
<th>GIS WALKABILITY INDEX PARAMETERS</th>
<th>PERCEIVED BUILT ENVIRONMENT (NEWS Africa Scale)</th>
<th>1000 m buffer Combined –SES</th>
<th>1000 m buffer Low-SES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walkability (Overall)</td>
<td>Destinations</td>
<td>Roads and Paths</td>
<td>Places for walking, cycling, playing</td>
</tr>
<tr>
<td>Land-use mix</td>
<td>0.0</td>
<td>0.2</td>
<td>0.3**</td>
</tr>
<tr>
<td>Intersection density</td>
<td>-0.2</td>
<td>0.3**</td>
<td>0.0</td>
</tr>
<tr>
<td>Residential density</td>
<td>-0.2</td>
<td>0.3</td>
<td>-0.1</td>
</tr>
<tr>
<td>Transport density</td>
<td>0.1</td>
<td>0.1</td>
<td>0.0</td>
</tr>
<tr>
<td>Walkability (Overall)</td>
<td>-0.2</td>
<td>0.3</td>
<td>0.1</td>
</tr>
<tr>
<td>Land-use mix</td>
<td>-0.2</td>
<td>0.4**</td>
<td>0.3</td>
</tr>
<tr>
<td>Intersection density</td>
<td>-0.5**</td>
<td>0.3</td>
<td>0.0</td>
</tr>
</tbody>
</table>
Residential density  | -0.1 | 0.0 | -0.1 | -0.2 | -0.2 | -0.5** | -0.2
Transport density  | 0.3  | 0.1 | -0.1 | -0.1 | -0.1 | -0.4  | 0.0

1000 m buffer High-SES
Walkability         | -0.2 | 0.1 | 0.3  | 0.2  | 0.0  | 0.0   | -0.1
Land-use mix        | -0.2 | 0.0 | 0.0  | -0.1 | -0.3 | 0.2   | -0.1
Intersection density| -0.3 | -0.1| 0.2  | 0.0  | 0.1  | -0.1  | 0.0
Residential density | 0.2  | -0.4**| -0.2 | 0.2  | 0.2  | 0.0  | -0.2
Transport density   | -0.1 | 0.2 | 0.3  | 0.1  | -0.1 | -0.1  | 0.0

*Spearman’s (rho) correlations of GIS measured walkability index parameters and the perceived built environment in 1000m*. **r-values are reported for only comparisons that were statistically significant at p <0.05.

5.3 The NEWS Africa survey divided in groups according to SES and GIS-measured walkability
We examined the scores for the perceived attributes of the built environment from the NEWS-Africa subscales in the 4 groups. These results are presented in Table 6. There was a significant difference in scores for Places for walking, cycling, and playing overall scale in the Low-SES/Low walkable vs High-SES/Low walkable groups (overall p = 0.008), indicating the differences were due to SES differences but not walkability. The Neighbourhood surroundings scale, representing the perceived neighbourhood aesthetics, was significantly lower in the Low-SES/Low walkable community when compared to Low-SES/High walkable and both High-SES groups.

Table 6: Comparisons of NEWS sub-scales by SES-Walkability Status (High-Low SES & Low-High Walkability) *

<table>
<thead>
<tr>
<th></th>
<th>Low-SES/ High-SES/Low W*</th>
<th>High-SES/Low W*</th>
<th>Low-SES/ High W*</th>
<th>High-SES/ High W*</th>
<th>P values**</th>
</tr>
</thead>
<tbody>
<tr>
<td>NEWS 1 SUB-SCALE</td>
<td>Median (lower and upper interquartile range)Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Places for walking,</td>
<td>2.7 (2.4; 2.8)</td>
<td>3.1 (2.8; 3.4)</td>
<td>2.8 (2.2; 2.9)</td>
<td>2.8 (2.7; 3.2)</td>
<td>Overall p = 0.008 1 vs 2 = 0.000</td>
</tr>
<tr>
<td>cycling, &amp; playing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Overall Mean)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neighbourhood</td>
<td>2.3 (1.8; 3.0)</td>
<td>3.5 (3.1; 3.8)</td>
<td>2.1(1.8;2.8)</td>
<td>3.9 (3.6;3.9)</td>
<td>Overall p = 0.00 1vs 4 = 0.000; 2vs 3 = 0.033 3 vs 4 = 0.000</td>
</tr>
<tr>
<td>surroundings</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Safety from Traffic</td>
<td>1.8(1.0;2.6)</td>
<td>2.6 (2.2;3)</td>
<td>1.0 (1.0;2)</td>
<td>2.8 (2.3)</td>
<td>Overall p=0.000</td>
</tr>
</tbody>
</table>
Safety from Crime 1.3 (1.3;1.5) 3.0 (2.8;3.5) 1.0 (1.0;1.5) 3.0 (2.5;3.3) Overall p= 0.000 1 vs 2 = 0.001; 1 vs 4 = 0.000 2 vs 3 = 0.000; 3 vs 4 = 0.002

Personal safety 2.7 (2.3;3.0) 2.7 (2.7;3.0) 2.7 (2.7;3.0) 3.3 (2.7;3.3) Overall p= 0.012 3 vs 4=0.0146

Stranger danger 4.0 (4.0;4.0) 3.0 (2.0;4.0) 3.3 (3.0;4.0) 2.5 (1.8;3.2) Overall p = 0.004. 1 vs 4 = 0.004

*Kruskal-Wallis tests were used to present the multiple comparisons between NEWS Sub-scale and SES-W

* w-wallability; ** p-values are reported for only comparisons that were statistically significant - p-value<0.05 (N/B: 1 vs 4 – means low-SES-Low Walkability category vs. High SES-High Walkability categories). Figures presented on the table are based on median, lower and upper interquartile ranges.

The Safety from Traffic scale was significantly lower in the Low-SES, High walkable group, compared to both High-SES groups, with residents in both High-SES communities reporting a higher perception of safety from traffic. With respect to the Safety from Crime scale, persons from Low-SES groups felt significantly less safe than their High-SES counterparts, again irrespective of walkability (overall p = 0.000). In terms of Personal safety, this subscale only differed between the High-SES and Low-SES, High walkable groups (Overall P = 0.012). The Stranger danger scale was only significantly different between the extremes of Low-SES, Low walkable and High-SES, High walkable groups (overall P = 0.004).

6.0 Discussion

In broadening the research on associations between the built environment and physical activity, this study explored some aspects of the NEWS-Africa scale utilising ground-truthing and remote-sensing technology (Geographic Information Systems (GIS) in an urban South African setting.

Overall, three key findings stand out of this study. 1) no relationship between any self-reported physical activity and GIS-measured walkability index parameters by income level; 2) only intersection density correlated with measured physical activity; 3) a significant difference in the self-reported physical activity in the domain of transport with High-SES/Low walkable vs. Low-SES/ High walkable. Specifically, residents in the Low-SES/High walkable neighbourhoods reported more transport-related physical activity compared to High-SES/Low walkable as highlighted in the conceptual model.

The study results suggest that even when the built environment is unsupportive for physical activity, people in low SES communities participate in more transport-related physical activity. Those individuals from high SES communities participate in more vigorous activity, even when they perceive the environment to be unsupportive. We assume that this is because they might be engaged in fitness-related or leisure time activity in destinations beyond their local community.
6.1 Perceptions of proximity compared to objectively measured distances.

There is limited evidence concerning the factors that influence an individual’s ability to accurately report on the features that are present in their neighbourhood (10). In this study, people in the high-SES and low-SES perceived destinations to be further way or nearer than they were. We, therefore, postulated various factors to explain these significant differences including salience, utility, choice and effects of the past socio-political environment in South Africa. Residents in the high–SES are more accustomed to driving and using private cars (17) to get to their various destinations and may therefore not be aware or sensitized to the distance they would have to cover if they walked on foot. On the other hand, the people in low-SES have limited access to private motor vehicles, and therefore generally rely on public transport to get to and from places.

Some studies revealed that the frequency of transportation is related to the proximity of destinations (18–20). Adams et al. (19), however argue that the destinations may be recalled more accurately because of their utility and salience and further note that destinations allow for real transactions to take place such as purchases and use of facilities, thereby presenting an opportunity to interact. It is therefore likely for one who walks to specific destinations to be able to recall its location and distance from home more accurately than someone who takes motorised transport. GIS measures of the built environment included the percent of commercial and institutional land uses, number of schools, colleges and recreational facilities, parks, transit stops and trees, land topography and traffic congestion. The study revealed that, compared with a 10 and 30-minute walking distance, the self-reported 20-minute walking distance to destinations generally had the strongest correlations with GIS measures.

People in the high-SES, perceived sports fields and places of worship to be further away than they actually were ($r_s = -0.60$ and $r_s = -0.50$, respectively, $P< 0.05$) and people in the low-SES and combined-SES perceived public bus/ train stop to be nearer than they actually were ($r_s =-0.50$, $P< 0.5$).

Studies suggest that the past structural inequalities of apartheid have rendered transit and transportation difficult and complicated to a broader South African context, especially in a Cape Town setting. Turok, (21) in South Africa, explains that the three most important structural elements of the cities are employment, housing and transport connections between them and these are critical in determining how efficiently and equitably cities function because they are critical resources for the poor. Access to these amenities has a significant effect on living standards and is competitively sought after.

Our findings show that the people in the low-SES and combined SES perceived Public bus/ train stops to be nearer than they actually were, and this underscores the inequities between SES communities as there is an underlying reason and implication for this perception. Guither and Weinstock, (22) reveal that Cape Town’s My Citi bus system has an intention to correct the apartheid planning that has put citizens of colour at a disadvantage. My Citi or Integrated Rapid Transit system was developed in 2008 and launched in May 2001 in the form of Bus Rapid Transit (BRT) trunk (central station and route ) and feeder services (23). What began as inner city and airport services coupled with specific routes on the corridor between the inner city and a northern middle-income suburb has expanded over time, and this relatively new bus system seeks to create a system that tries to correct the past structural inequalities of apartheid (22).
6.2 The relationship between the GIS measured walkability and the perceived built environment.
In the present study, Intersection density was positively associated with Roads and walking paths scale in the combined –SES but not in the low- and high –SES, Places for walking cycling, playing and overall mean were not associated with Intersection density in all the SES groups. Previous studies that have reported on intersection density (as an objective measure of perceived street connectivity), have highlighted that intersection density was associated with walking (24), but not with cycling (25). There were no correlations between intersection density was associated and walking. It is believed that people in the low-SES alternatively used the informal routes irrespective of the set structures put in place because they are overcrowded with high density of slum settlements. Importantly, there are no planned open spaces such as parks or playgrounds or people in low-SES formal places like parks, green spaces as these spaces are used for housing and infrastructure (26). The Neighbourhood surroundings scale in our study had a positive association with the land use mix and a negative association with residential density when groups were combined. In the low-income groups, intersection density was associated with greater safety from crime, whereas residential density was inversely associated with personal safety. A previous study by Mackenbach et al., (27), had provided evidence that socioeconomic differences in neighbourhood perceptions are associated with objective neighbourhood measures.

6.3 Perceptions of the built environment (walkability) in high- and low-SES
Compared to people in high-SES, those with a lower-SES are more likely to perceive their neighbourhood as unattractive and unsafe, which in turn may be related to low levels of physical activity. Sugiyama et al. (17) highlight that persons living in high SES communities people may prefer to walk in their neighbourhoods, with fewer safety concerns from crime and traffic. Kamphuis et al.(28), showed that agreement between objective and perceived environmental factors is often found to be low and underscore that it is questionable to what extent creating supportive neighbourhoods would change neighbourhood perceptions. The differences in Safety from Crime, Personal safety and Stranger danger perceptions in the current study may be due to the fact that people in the low-SES area may be more "accommodating" about what is safe for them and have become accustomed to the general crime and insecurity that seems to be pronounced in the South African low-SES areas (29). This is corroborated by Manaliyo, (30) in which he shows that residents in Khayelitsha, the largest socio-economically poor township in Western Cape Province recognise that the crime rates are high, frequent and unpredictable. However, he argues that poverty and unemployment must have contributed to the high crime rate reported. We support therefore the suggestion that the impact of perceived safety from crime on walking and other forms of physical activity needs to be further investigated (31) (32)(33). The differences in the Safety from Traffic scale in the present African study are of importance, as they suggest a difference in the expectations of respondents, as regards traffic safety and safety from crime.

6.4 Strengths and limitations
The present study has critical limitations to note, these include the method of recruitment, small sample size, which have been highlighted in the previous chapter. An additional limitation in this study is the definition used for street network, which may not correspond with the participants' perceptions of the boundaries of their own neighbourhoods. Participants may consider their neighbourhoods further or closer than the set boundaries, especially after they are asked the same question for different items. Adams et al.
underscore that the NEWS prefacing items in the land-use mix access (e.g. 10-15) minutes' walk from one’s home may attenuate the observed relationships for other items. The strengths of the present study include being the first study in the region to compare neighbourhood environmental perceptions and objectively measured attributes of the built environment related to walkability. To our knowledge, a “ground truthing” study of neighbourhood “walkability” has not been conducted in Africa, we believe this is important in better understanding the impact of environmental attributes on; incidental, utilitarian, and leisure-time physical activity in order to structure interventions, and to address issues of environmental justice. Geographical Information System (GIS) can be used to objectively measure features of the built environment that may influence adult physical activity, an essential determinant of chronic disease (35).

6.5 Recommendations and Conclusion
These findings are particularly significant for health promotion in low income setting in South Africa. Lee et al., 2012 (36) highlight that understanding the environmental correlates of physical activity is a priority that could lead to better strategies to prevent further declines in physical activity in the region and have implications for policies and strategies that lie outside the health sector. From an African and South African perspective, we may be able to adapt and implement strategies used in other African cities and nations, including Tanzania (37) Ghana, Niger, Uganda (38) and Rwanda(39).

There is the need for local governments to play important roles in addressing environmental justice to promote physical activity, for promoting the development and use of public spaces. Policy makers can develop policies to support equitable access and use of public spaces, and promote inclusive, safe and quality public spaces (39). For researchers, especially in future studies, measuring social and cultural environments especially in the LMICs, will aid in understanding their impact/role in enhancing or inhibiting PA. Analyses that include variables from multiple levels of ecological models would be appropriate in explaining human behaviour.

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Conflicts of Interest:
The authors report no declaration of conflicts of interests.

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