Using Urban Design Qualities for Building a New Composite Walkability Index for Cairo Streets

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Abstract:
This paper aims to build a Composite Walkability Index (CWI) for Cairo Streets. It is based on the field manual of the study of Ewing and Clemente (2013) to determine the most relevant Urban Design Qualities (UDQs) and physical features of walkability. The CWI is constructed in two stages; the Benefit-of-the-Doubt (BOD) weighting scheme is applied to each one. The reason for applying this mathematical programming method is to endogenously determine the relative importance of all UDQ and physical features with respect to walkability. Therefore, to investigate the credibility of the BOD technique, it has been applied to a sample of 46 different paths from Cairo streets. The resulted CWI values are discriminated such that no two streets have the same score. This in turn helps decision makers to assess these streets by relying on the distinguishable ranks of CWI and UDQs.

Keywords:
Benefit-of-the-Doubt (BOD)
Composite Indicators (CIs)
Composite Walkability Index (CWI)
Urban Design Qualities (UDQs)
Physical features.

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1. Introduction

Walkability is a measure of how friendly an area is to walking. It is referred to as, the extent to which walking is readily available as a safe, connected, accessible and pleasant mode of transport *(Abley and Turner 2011*. "Other references including Seilo mentions "Walkability - is a measure of the urban form and the quality and availability of pedestrian infrastructure contained within a defined area. Pedestrian infrastructure includes amenities developed to promote pedestrian efficiency and safety such as sidewalks, trails, and pedestrian bridges."(*Abley and Turner 2011).* The USA National Centre for Chronic Disease Prevention and Health Promotion defines "Walkability is the idea of quantifying the safety and desirability of the walking routes".

Walkability has many health, environmental, and economic benefits. Increased walkability has proven to have many other individual and community health benefits, such as opportunities for increased social interaction, an increase in the average number of friends and associates where people live, reduced crime rates (with more people walking and watching over neighborhoods, open space and main streets), increased sense of pride, and increased volunteerism. Another benefit of walkability is the decrease of the levels of overweight and obesity among people. According to the World Health Organization, 1.5 billion adults were overweight in 2008, and approximately 500 millions of these adults were obese (*World Health Organization [WHO], 2011)* Given concern over increasing levels of overweight and obesity, identifying and modifying related built environment characteristics may be an important policy step for chronic disease prevention. One of most important benefits of walkability is the decrease of the automobile footprint in the community. Carbon emissions can be reduced if more people choose to walk rather than drive. It has also been found to have many economic benefits, including accessibility, cost savings both to individuals and to the public, increased efficiency of land use, increased livability, economic benefits from improved public health, and economic development among others. *(Mohammad H. Refaat and Nezar A. Kafaf,2014)*

Evaluating the role of urban design characteristics at street level is still a matter of subjectivity (Abley and Turner 2011). Therefore, adopting an objective scientific approach for measuring street features will help policymakers enhance the quality of the pedestrian environment. To quantify street walkability, which is a great challenge, a large number of studies suggested building a composite index of walkability. The idea of this index is to assemble all features together into one index to determine the influence of each indicator on the final score.

Walkability indices have been introduced in the literature at the neighborhood and street levels. At the macro level, neighborhood, there are examples such as Walk Score (Walk Score 2017) and Space Syntax model (Hillier et al. 1993). On the other hand, there is a limited number of walkability indices at the micro level, streets. The reason is that these indices depend on the perception of the environment, i.e. people's preferences. Furthermore, walkability indices cannot be assessed by relying on pedestrian flows since a street of a large number of people walking on it is due to several factors such as density or connectivity (Neto 2015).

There are online attempts to assess walkability of streets based on users' perceptions. For instance, "*Rate My Street"* evaluates streets using a five-star rating system (TRL 2014). Moreover, this index depends on eight categories to assess streets. Another online application is walkanomics (Walkanomics 2017) that estimates the quality of streets on a scale of zero to 5.

A remarkable contribution to the assessment of streets was introduced by Ewing and Clemente (2013). The authors relied on expert panels to evaluate walkability and urban design qualities for a sample of New York streets. Moreover, they investigated statistical relationships between ratings of expert panels and the physical measurements of these streets.

It is worth noting that the previous review of studies that constructed walkability indices is not comprehensive. The literature includes several trials to quantify this term (Park 2008; Neto 2015; ALasadi 2016).

This study adopts the same definitions of Urban Design Qualities (UDQ) and physical features of the study of Ewing and Clemente (2013). Nevertheless, the proposed methodology, to construct a Composite Walkability Index (CWI), follows the ten-step technique of the Organization of Economic Cooperation and Development (OECD 2008) to reliably assess Cairo streets.

2. Overview of CIs Construction (OECD 2008)

Composite Indicators (CIs) are widely accepted as a useful tool in different disciplines such as economy, environment and society (OECD 2008). Moreover, they are used to summarize multidimensional phenomena and assess the progress of different units over time. Despite the common use of CIs, they remain controversial since they provide decision makers with unreliable information if they are poorly constructed. Therefore, OECD (2008) introduced ten steps to build a robust CI. The first step defines the theoretical framework of the multi-dimensional phenomenon to be evaluated. The second step, data selection, focuses on assessing the available indicators that will be used for measuring the complex issue. The third step handles the problems of missing data and outliers. In the fourth step, multivariate analysis is applied to explore the overall structure of the dataset. In the fifth step a suitable normalization method is carried out to overcome the effect of different units of measurements. The next step, weighting and aggregation, assigns a weight for each sub-indicator to combine them into a single index. In addition, this step is considered the most crucial as it reflects the sub-indicators' importance (Zhou et al. 2012). The coming steps are mainly concerned with the reliability of the constructed CI. These steps are: conducting sensitivity analysis for assessing CI, decomposing the CI into the original indicators, linking CI to other indexes for deeper analysis and finally presenting the results in a clear visual way (OECD 2008).

Due to the importance of weighting process, several classifications were introduced in the literature for determining them. For instance, OECD (2008) defined two weighting schemes: *the statistical and the participatory* approaches. The first one evaluates sub-indicators' weights from the data without any interference from the researcher. It includes methods such as Principal Component Analysis (PCA), regression analysis (a technique used in the study of Ewing and Clemente (2013) to assign weights for physical features and urban), and Benefit-of-the-Doubt (BOD), which is adopted in this study. The second classification, on the other hand, determines weights exogenously such as imposing equal weights or depending on experts' opinion.

Before illustrating the proposed methodology, the BOD, for assigning weights for the components of walkability, it is important to clarify the theoretical framework of this study. The main objective of this paper is to build a Composite Walkability Index (CWI) for Cairo streets on the basis of how friendly they are for pedestrians. The proposed CWI is calculated using two-stage BOD approach. In the first stage, each urban design quality (imageability- enclosure- human scale- transparency- complexity) is estimated for each street using a group of physical features, which are evaluated from the data collected from Cairo streets. Moreover, these qualities have the major impact on the overall walkability (Ewing and Clemente 2013). In the second stage, the overall CWI is obtained for each street by relying on the estimated values of urban design qualities.

Figure (1) below illustrates the two-stage structural components of the CWI. The classification of physical features under each urban design quality is slightly different from that of the field manual of Ewing and Clemente (2013). In the manual, these physical characteristics exist in an overlapping pattern between the five urban design qualities. This is not the case in this study. For building a robust CWI, all dimensions, i.e. the five urban design qualities, should be mutually exclusive in the sense that the effect of each physical feature should appear once on the overall CWI. In addition, this study depends on the results of Ewing and Clemente (2013) to determine these relationships. For instance, in the study of Ewing and Clemente (2013), the physical feature *"proportion of active uses"* is classified under two urban design qualities, human scale and transparency, with two different weights, at 0.306 and 0.533 respectively. Nevertheless, this study assumes that this physical feature is involved in transparency only since it has a higher weight, keeping other variables fixed.

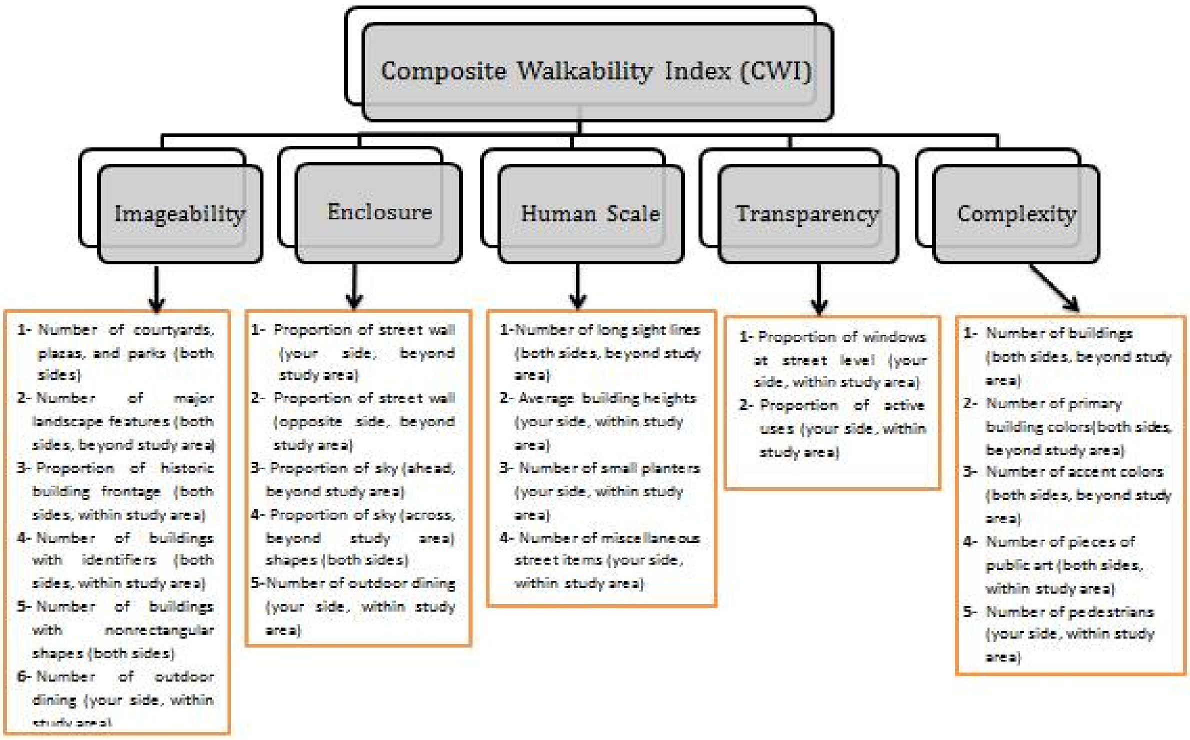

Figure (1): Components of the CWI

3. *The Proposed Methodology for Building a CWI*

Although there is no one-and-only true CI (Saisana and Tarantota 2002), this paper introduces an objective method for assessing the walkability issue in any street. The proposed methodology is built on the BOD technique, which is an application of the technique of Data Envelopment Analysis (DEA) to the field of CIs (OECD 2008). The essence of the BOD method is to provide each unit, street in this study, with the highest level in the CWI through maximizing the sub-indicators' weights.

The following BOD model, which is used in this study, is a Linear Programming (LP) model that is mathematically formulated as Model (1) below.

Model (1): BOD Model (Cherchye et al. 2007)

$$UDQ_n = max_{w_{rn}} \sum_{r=1}^{R} w_{rn} I_{rn}, \qquad n = 1,2,\dots,N \qquad (1)$$

Subject to:

$$\sum_{r=1}^{R} w_{rn} I_{rk} \leq 1, \qquad k = 1,2,\dots,N \qquad (2)$$

$$w_{rn} \geq 0, \qquad r = 1,2,\dots,R \qquad (3)$$

The above-mentioned model is applied in the first stage to get a score for all UDQ for each street. It is repeated *N* times, once for each street *n* (n = 1,2,…,N), when it is applied to each urban design quality. The symbol I_{rn} indicates the value of physical feature *r* (r =1,2,..,R) for street *n* and the corresponding weight is w_{rn}. Equation (1), the objective function, maximizes the UDQ for each street *n* (n = 1,2,…,N) through maximizing the weights w_{rn}. Furthermore, Equation (2), the first constraint, guarantees that the UDQ for each street does not exceed one since the resulting values range between zero (the lowest performance) and one (the highest performance). The last constraint, Equation (3), ensures the non-negativity of the weights of physical features.

In the second stage, the CWI is calculated using the same model after slightly changing the form of the objective function, Equation (4) below, and keeping the above two constraints fixed. Consequently, the overall CWI is calculated for each street as follows:

$$CWI = \sum_{t=1}^{5} w_{tn}^{*} \sum_{r=1}^{R} w_{rn} I_{rn}, \qquad n = 1,2,\dots,N \tag{4}$$

The symbols I_{rn} and w_{rn} are defined as in Model (1) above. The sum $\sum_{r=1}^{R} w_{rn} I_{rn}$ is evaluated from Model (1) above and it stands for the UDQ_{tn}, which is the urban design quality *t* (t= 1,2,..,5) for street *n*. The corresponding weight, w_{tn}^{*}, represents the effect of each urban design quality on the overall walkability.

It is worth mentioning here that the BOD model **(**Cherchye et al. (2007) and OECD (2008)**)** was applied in different contexts. For instance, Cherchye et al. (2007) applied this technique to evaluate the Technology Achievement Index (TAI) for 23 countries. Another example is the composite sustainability index of Zhou et al. (2012). Blancas et al. (2013) applied this technique to evaluate CI scores for 20 firms in the fast-food franchising sector in Spain.

The BOD technique has several advantages compared to other weighting methodologies. First, the sub-indicators' weights **(**a term used in this paper to refer to physical features in the first stage or UDQ if talking about the second stage**)** are endogenously evaluated from the data. Second, the CI **(a** term used to refer to an overall index, i.e. UDQ in the first stage or CWI in the second stage**)** is assessed for each unit such that its value is maximized to the greatest level. Finally, the BOD model is computationally straightforward since it depends on mathematical programming.

Inspite of the above-mentioned merits, the BOD technique has several shortcomings. Without imposing restrictions on weights, apart from the non-negativity constraint, the majority of units obtain a CI value equals to one which reduces the discriminating power of the model (Cherchye et al. 2007). Another issue is that the effect of some sub-indicators on the overall CI is ignored due to the problem of zero weights. Cherchye et al. (2007) addressed this problem through adding lower and upper bounds to the weights. However, this restriction requires a priori information about these weights which may not be valid.

To overcome the previously mentioned limitations, this paper applies the approach of Cook et al. (1996) that set an endogenous lower bound, ε, on sub-indicators' weights. The essence of the approach of Cook et al. (1996) is endogenously estimating a lower bound on weights. Through applying this approach to the BOD model, the above-mentioned drawbacks are tackled. Consequently, the approach of Cook et al. (1996) for evaluating the non-Archimedean infinitesimal, ε, reinforces the discriminating power of the BOD model and handles the problem of zero weights.

From the above-mentioned discussion, the proposed methodology for building a reliable CWI for Cairo streets is based on two major steps. These steps will be implemented for each stage to avoid the problems of discrimination and zero weights as follows:

i) Determining a lower-bound, ε, on sub-indicators' weights through applying the approach of Cook et al. (1996) to the BOD model, as shown in Model (2) below.

ii) Evaluating a CI for each street using the BOD model, i.e. Model (1) above, after taking the estimated ε value into account.

Model (2): Estimating the ε value using the BOD Model (Cook et al. 1996)

$$z = \max_{w_{rn}} \ \varepsilon \tag{5}$$

Subject to:

$$\sum_{r=1}^{R} w_{rn} I_{rk} \le 1, \qquad k = 1,2,\dots,N; \quad n = 1,2,\dots,N \tag{6}$$

$$w_{rn} \ge \varepsilon, \qquad r = 1,2,\dots,R; \quad n = 1,2,\dots,N \tag{7}$$

The symbols used are defined as in Model (1) above. This model is implemented once for all units. Equation (5), i.e. the objective function, maximizes the lower bound (ε) of weights to be large as much as possible. This is the essence of the approach of Cook et al. (1996) that was previously explained as a larger value of ε gives more discrimination to the CI values. Constraint (6) ensures that the CI value for each street n, i.e. $\sum_{r=1}^{R} w_{rn} I_{rn}$, does not exceed one. Equation

(7), the last constraint, sets **ε** as a lower bound on weights.

4. *Results of Applying the Proposed Methodology to Assess Walkability of Cairo Streets*

To show the importance of the proposed methodology, it has been applied to evaluate urban design qualities and walkability of a sample of Cairo streets. The data are collected from Cairo streets using the manual derived by the team of Maryland Inventory of Urban Design Qualities (MIUDQ) (Ewing and Clemente 2013). However, this study does not depend on experts' panel to evaluate walkability and urban design qualities of each street. The reason is that the subjectivity involved in the experts' opinion could lead to bias in the final results. Therefore, this study avoids subjective judgments in quantifying these intangible terms through applying the BOD approach.

The data are collected using a group of 120 persons who were extensively trained to correctly evaluate the physical features of each street. The team gathered the data of all physical features for 46 paths from 34 different streets. In addition, all paths are of equal length, 1000 meters, for the purpose of fair comparison. Although it is preferred to use a random sample when selecting streets, this study adopts different criterion. The historical background of these streets was the major reason for their choice since their physical features are more valuable. Furthermore, all streets are chosen from Cairo governorate, in Egypt, since the author is familiar with this area, which makes it easier to find suitable streets for the purpose of this study.

Table (1) below shows descriptive measures (mean-median-standard deviation-minimum value-maximum value) for each physical feature of the chosen Cairo streets. Overall, the median is remarkably below the mean, which suggests that a distribution skewed to the right.

Another point that should be clarified is that this study excludes the ordinal variables used in the study of Ewing and Clemente (2013) such as the variable "noise level" that is rated from one (the lowest level) to five (the highest level). The reason for this exclusion is that these variables make the BOD model more complicated. The simple BOD approach, i.e. Model (1), handles ratio scale variables. Therefore, adding ordinal variables require further analysis (Shen et al. 2011).

Table (1): Descriptive Statistics for Physical Features of Cairo Streets Before applying the proposed methodology, the normalization process should be implemented

	Physical Features	Mean	Median	SD	Min	Max
Imageability						
	Number of courtyards, plazas, and parks	0.696	0	1.245	0	7
	Number of major landscape features	0.022	0	0.147	0	1
	Proportion of historic building frontage	0.238	0.035	0.338	0	1
	Number of buildings with identifiers	11.913	6	14.593	0	67
	Number of buildings with nonrectangular shapes	5.652	3	7.109	0	33
	Number of outdoor dining	1.435	0	2.136	0	8
Enclosure						
	Proportion of street wall - your side	0.837	0.835	0.073	0.6	0.98
	Proportion of street wall - opposite side	0.779	0.85	0.209	0	0.98
	Proportion of sky - ahead	0.324	0.3	0.14	0.05	0.73
	Proportion of sky - across	0.356	0.3	0.197	0.1	0.9
Human Scale						
	Number of long sight lines	0.913	1	0.626	0	2
	Average building heights	19.739	18	7.255	6	32
	Number of small planters	20.565	5.5	62.18	0	382
	Number of miscellaneous street items	32.348	40	12.699	3	40
Transparency						
	Proportion of windows at street level	0.65	0.7	0.177	0.2	0.92
	Proportion of active uses	0.592	0.665	0.294	0.1	1
Complexity						
	Number of buildings	132	45	602.259	14	4126
	Number of primary building colors	2.283	2	1.068	1	6
	Number of accent colors	3.826	2.5	3.826	1	23
	Number of pieces of public art	0.217	0	0.467	0	2
	Number of pedestrians	183.848	139.5	157.232	20	857

Normalization is essential to get rid of the effect of different units of measurements (OECD 2008). The "*Min-Max*" normalization method is adopted in this study. However, it is necessary to highlight the direction, positive or negative, of these physical features to the CWI before normalization.

The direction of these variables is clearly shown in Column (4) of Table (3). Moreover, Equation (8) below is used for the normalization process if the variable has a positive direction, i.e. the higher, the better. On the other hand, Equation (9) is applied if the variable, i.e. physical feature, has a negative contribution to the CWI.

$$Index = \frac{actual\ value - minimum\ value}{maximum\ value - minimum\ value} \quad (8)$$

$$Index = \frac{maximum\ value - actual\ value}{maximum\ value - minimum\ value} \quad (9)$$

It is worth mentioning that the log transformation, which is applied to two variables; number of buildings and number of pedestrian is applied to some variables due to the presence of outlier cases. This transformation is applied before the normalization process as follows:

$$Index = \frac{\log(actual\ value) - \log(minimum\ value)}{\log(maximum\ value) - \log(minimum\ value)} \quad (10)$$

The proposed BOD method is applied to each dimension, i.e. urban design quality, which composes walkability. Table (2) below illustrates the estimated imageability values and ranks for the selected paths of Cairo. The results of the remaining urban design qualities are displayed in Columns (2)-(5) in Table (4). Also, the results show that all physical features have equal importance, weights, in each urban design quality as clearly shown in Column (5) of Table (3) in the appendix. In addition, the five urban design qualities have the same effect on the overall walkability, Column (2) of Table (3). The reason for the above-mentioned cases is that the approach of Cook et al. (1996) sets a lower bound on these weights that if ignored leads to zero weights in some variables. This approach has the advantage of enhancing the discriminating power of the BOD model.

To assess the reliability of the proposed CWI, it has been related to other indexes. However, to the best of our knowledge, there is no study that evaluated the same, or some of, Cairo streets using the same criteria so that a fair comparison can be made. The website "*walkscore.com*" (Walk Score 2017) is used to calculate walkability for each of the given streets, Column (7) of Table (4) in the appendix. Moreover, these scores are very high, which indicates that the chosen streets are highly walkable. The author tried to find if the there is a link between the CWI values, Column (6) of the same table, and these scores. Nevertheless, the results show a low correlation between them. This was expected since this website evaluates walkability using macro-scale indicators, such as housing density and land use diversity, which cannot capture the effect of urban design qualities of a street on the walking behavior. This is not the case in the proposed CWI that assesses walkability on the micro-level, i.e. street level.

Table (2): Estimated Imageability Scores and Ranks for Cairo Streets

Path ID	Name	Imageability [a]	Path ID	Name	Imageability [a]
1	Al Sabtiah	0.53 (8)	24	El Nozha	0.089 (39)
2	El-Gomhoreya	0.236 (29)	25	Fareed Semeika	0.208 (31)
3	Al Fagalh	0.315 (24)	26	Fareed Semeika	0.202 (32)
4	EL-Galaa	0.08 (40)	27	Baghdad	0.358 (20)
5	Ramses	0.265 (26)	28	Baghdad	1 (1)
Path ID	**Name**	**Imageability [a]**	**Path ID**	**Name**	**Imageability [a]**
6	Kolot bak	0.139 (36)	29	Ibrahim	0.358 (20)
7	Mahamed Mahmoud	0.692 (4)	30	EL-Thawra	0.331 (23)
8	Tallat Harb	0.486 (11)	31	EL-Nozha	0.106 (37)
9	Talaat Harb	0.166 (33)	32	Abbas EL-Akkad	0.239 (28)
10	Talaat Harb	0.466 (13)	33	EL Nasr street	0.402 (18)
11	Kasr Al Nile	0.477 (12)	34	EL Nasr street	0.729 (3)
12	Kasr El-Nile	0.449 (14)	35	Makram Ebeid	0.407 (17)
13	AL Bustan	0.231 (30)	36	Omar Ibn El-Khattab	0.503 (9)
14	Champollion St	0.44 (15)	37	Syria	0.069 (42)
15	Opera	0.293 (25)	38	Wadi Al Nile	0.08 (40)
16	Mahmoud Bassiouny	0.349 (22)	39	Gameat AL Dewal	0.553 (6)
17	Mohammed Sabri Abou Alam	0.438 (16)	40	Lebanon	0.161 (35)
18	EL-Qobba	0.261 (27)	41	Lebanon	0.38 (19)
19	EL-Khalifa El-Maamoun	0.046 (45)	42	Gohar El Qaeed	0.531 (7)
20	EL Hegaz	0.035 (46)	43	Gohar El Qaeed	0.636 (5)

21	El Hegaz	0.069 (42)	44	Port Said	0.059 (44)
22	El Hegaz	0.094 (38)	45	Port Said	0.163 (34)
23	Ibrahim Al Lakani	0.501 (10)	46	Al Moez Ledin Allah El Fatemy	0.924 (2)

[a] Ranks are shown in parentheses. The imageability values and ranks are calculated at the seventh decimal place. The written values are approximated to the nearest third decimal place.

It is worth mentioning here that the BOD methodology has been executed using the *General Algebraic Modelling System (GAMS)* software. Applying this methodology to Cairo streets does require less than a second to be implemented.

Table (3): Weighting Scheme for Physical Features and Urban Design Qualities

(1) Dimension	(2) Dimension's Weight	(3) Basic Indicators (physical features)	(4) Direction	(5) Indicators' weights
Imageability	0.221	Number of courtyards, plazas, and parks	+	
		Number of major landscape features	+	
		Proportion of historic building frontage	+	0.381
		Number of buildings with identifiers	+	
		Number of buildings with nonrectangular shapes	+	
		Number of outdoor dining	+	
Enclosure	0.221	Proportion of street wall-same side	+	
		Proportion of street wall-opposite side	+	0.255
		Proportion of sky ahead	-	
		Proportion of sky across	-	
Human Scale	0.221	Number of long sight lines	-	
		Average building heights	-	0.342
		Number of small planters	+	
		Number of miscellaneous street items	+	
Transparency	0.221	Proportion of windows at street level	+	0.507
		Proportion of active uses	+	
Complexity	0.221	Number of buildings	+	
		Number of primary building colors	+	
		Number of accent colors	+	0.403
		Number of pieces of public art	+	
		Number of pedestrians	+	

Table (4): Values and Ranks for Four Urban Design Qualities, CWI and Walk Score in Cairo streets

Path ID	(1) Name	(2) Enclosure	(3) Human scale	(4) Transparency	(5) Complexity	(6) CWI	(7) Walk Score
1	Al Sabtiah	0.745 (18)	0.849 (7)	0.901 (3)	0.497 (21)	0.727 (6)	85
2	El-Gomhoreya	0.724 (21)	0.687 (17)	0.746 (19)	0.699 (7)	0.612 (13)	93
3	Al Fagalh	0.636 (29)	0.874 (6)	0.366 (36)	0.66 (8)	0.561 (18)	89
4	EL-Galaa	0.748 (17)	0.709 (16)	0.239 (42)	0.441 (26)	0.411 (33)	89
5	Ramses	0.605 (36)	0.344 (45)	0.338 (38)	0.651 (9)	0.364 (40)	85
6	Kolot bak	0.792 (13)	0.769 (13)	0.211 (43)	0.446 (24)	0.452 (29)	90
7	Mahamed Mahmoud	0.812 (8)	0.658 (21)	0.456 (28)	0.472 (22)	0.614 (11)	94
8	Tallat Harb	0.759 (16)	0.487 (36)	0.417 (33)	0.612 (15)	0.519 (23)	94
9	Talaat Harb	0.835 (6)	0.66 (19)	0.493 (26)	0.416 (28)	0.498 (26)	94
10	Talaat Harb	0.842 (4)	0.596 (26)	0.901 (3)	0.278 (38)	0.614 (12)	94
11	Kasr Al Nile	0.797 (12)	0.671 (18)	0.411 (34)	0.873 (2)	0.646 (9)	94
12	Kasr El-Nile	0.792 (13)	0.45 (38)	0.901 (3)	0.272 (40)	0.546 (20)	94
13	AL Bustan	0.622 (32)	0.487 (36)	0.469 (27)	0.559 (20)	0.417 (32)	96
14	Champollion St	0.899 (2)	0.658 (21)	0.572 (25)	0.645 (10)	0.652 (8)	92
15	Opera	0.832 (7)	0.488 (35)	0.282 (41)	0.713 (6)	0.49 (27)	79

16	Mahmoud Bassiouny	0.703 (24)	0.528 (33)	0.113 (45)	0.159 (45)	0.306 (43)	87
17	Mohammed Sabri Abou Alam	0.557 (39)	0.298 **(46)**	0.366 (36)	0.218 (44)	0.281 (45)	95
18	EL-Qobba	0.842 (4)	0.66 (19)	0.824 (12)	0.241 (43)	0.56 (19)	89
19	EL-Khalifa El-Maamoun	0.739 (19)	0.592 (27)	0.451 (29)	0.336 (33)	0.39 (37)	79
20	EL Hegaz	0.615 (33)	0.571 (29)	0.07 **(46)**	0.044 **(46)**	0.183 **(46)**	88
21	El Hegaz	0.612 (34)	0.392 (41)	0.711 (21)	0.285 (37)	0.341 (41)	88
22	El Hegaz	0.658 (27)	0.383 (42)	0.817 (13)	0.361 (32)	0.401 (34)	88
23	Ibrahim Al Lakani	0.635 (30)	0.947 (4)	0.93 (2)	0.638 (12)	0.755 (5)	94
24	El Nozha	0.681 (26)	0.38 (43)	0.754 (18)	0.275 (39)	0.372 (39)	91
25	Fareed Semeika	0.632 (31)	0.41 (39)	0.782 (15)	0.265 (41)	0.397 (35)	90
26	Fareed Semeika	0.645 (28)	0.4 (40)	0.782 (15)	0.251 (42)	0.394 (36)	90
27	Baghdad	0.811 (9)	0.787 (12)	0.665 (23)	0.424 (27)	0.617 (10)	95
28	Baghdad	0.606 (35)	0.748 (14)	0.846 (10)	0.387 (30)	0.72 (7)	95
30	EL-Thawra	0.719 (22)	0.789 (11)	0.434 (32)	0.468 (23)	0.537 (21)	94
31	EL-Nozha	0.315 **(46)**	0.547 (31)	0.451 (29)	0.586 (18)	0.31 (42)	91
32	Abbas EL-Akkad	0.529 (40)	0.544 (32)	0.873 (7)	0.844 (3)	0.568 (17)	92
33	EL Nasr street	0.396 (45)	0.568 (30)	0.31 (40)	0.616 (14)	0.384 (38)	84
34	EL Nasr street	0.5 (41)	0.497 (34)	0.437 (31)	0.606 (16)	0.498 (25)	84
35	Makram Ebeid	0.486 (43)	0.376 (44)	0.38 (35)	0.332 (34)	0.305 (44)	92
36	Omar Ibn El-Khattab	0.694 (25)	0.602 (25)	0.211 (43)	0.298 (36)	0.417 (31)	85
37	Syria	0.732 (20)	0.834 (8)	0.739 (20)	0.596 (17)	0.597 (14)	94
38	Wadi Al Nile	0.804 (11)	0.798 (9)	0.317 (39)	0.41 (29)	0.468 (28)	73
39	Gameat AL Dewal Al Arabeya	0.583 (37)	0.882 (5)	0.866 (9)	1 **(1)**	0.798 (4)	97
40	Lebanon	0.431 (44)	0.658 (21)	0.62 (24)	0.643 (11)	0.448 (30)	92
41	Lebanon	0.563 (38)	0.658 (21)	0.676 (22)	0.816 (4)	0.594 (15)	92
42	Gohar El Qaeed	0.873 (3)	0.987 (2)	0.831 (11)	0.563 (19)	0.81 (3)	89
43	Gohar El Qaeed	0.772 (15)	0.987 (2)	0.775 (17)	0.718 (5)	0.824 (2)	89
44	Port Said	0.714 (23)	0.579 (28)	0.901 (3)	0.445 (25)	0.513 (24)	89
45	Port Said	0.806 (10)	0.724 (15)	0.873 (7)	0.373 (31)	0.588 (16)	89
46	Al Moez	1 **(1)**	1 **(1)**	1 **(1)**	0.627 (13)	1 **(1)**	89

[a] Ranks are shown in parentheses. The four urban design qualities and CWI values are calculated at the seventh decimal place. The written values are approximated to the nearest third decimal place.

5. Discussions of the BOD Findings

Applying the BOD methodology to assess walkability of Cairo streets proves several merits that are introduced in this section to show the remarkable contributions of this technique to this study. Firstly, the BOD technique equally maximizes the CWI and urban design qualities for all streets. Consequently, subjective judgments and biased results are avoided. Secondly, weights of physical features and urban design qualities are endogenously determined which matches with the essence of the BOD method. Thirdly, all sub-indicators and dimensions of walkability have been taken into account since the approach of Cook et al. (1996) is applied to the BOD model. Therefore, the problem of zero weights is diminished. Another merit is that the execution time of the BOD model is very fast; although, there are two stages required to get the final scores of the CWI. Finally and most importantly, all the selected streets have distinguishable rankings. These in turn help decision makers develop these streets by relying on the scores of the CWI and urban design qualities.

6. Comparing Statistical Analysis Results with Qualities of Urban Design:

In this part of the study, a revision of the analytical statistical study that used the BOD model was revised to derive the extent to which the statistical analytical study results are linked to the qualities of urban design: the three chosen streets were the streets that had the first ranking in each quality for revision and analysis to be compared to the statistical analysis results.

6.1 Imageability:

The result of statistical analysis showed that the best streets in terms of Imageability is Baghdad St with score of one, where the Proportion of artistic, architecture and historical building frontage (both sides, within study area) reaches 94% as shown in fig 1, The Number of buildings with identifiers (both sides, within study area) is 3 buildings, The Number of buildings with nonrectangular shapes (both sides)is 33 buildings, the Number of outdoor dining within study area 4 and the Number of pedestrians 132. The next street in the ranking is a AL Moez St. with score 0.924, where the Proportion of historic building frontage (both sides, within study area) is 70 % as shown in fig 2, The Number of buildings with identifiers (both sides, within study area) is 50 buildings, Number of buildings with nonrectangular shapes (both sides within study area)is 20 buildings, The Number of outdoor dining (within study side)is 3 and the Number of pedestrians (within study side) exceeds 450 person during the daytime. The Third street in the ranking is EL Nasr street with score of 0.729, where the Proportion of historic building frontage exceeds 0 %, The Number of buildings with identifiers (both sides, within study area) is 9 buildings as shown in Fig 3, Number of buildings with nonrectangular shapes (both sides within study area) is 1 buildings, The Number of outdoor dining (within study side) is 6 and the Number of pedestrians (within study side) exceeds 225 person during the daytime .By reviewing the physical features that affect the Imageability, these streets achieved large factors and are valid for statistical analysis.

Fig 1. Baghdad St


Fig 2 AL Moez St


Fig 3 EL Nasr street

6.2 Enclosure

The result of statistical analysis showed that the best streets in terms of enclosure is AL-Moez St with score of one, where the Number of long sight line equal zero, Proportion of street wall (within study side beyond study area) is 98%, Proportion of sky (ahead, beyond study area) is 10% and the width of the street is narrow, which confirms the feeling of enclosure as shown in Fig 4. The next street in the ranking is a EL- Champollion St with score of 0.899, where the Number of long sight lines equal one, Proportion of street wall (within study side) is 90% Proportion of street wall (opposite side, beyond study area) is 94%, Proportion of sky (ahead, beyond study area) is 20% and Proportion of sky (across, beyond study area) is 10% as shown in Fig 5,which confirms the feeling of enclosure but less than AL Moez St. The third street in the ranking is a Gohar EL Qaeed St with score of 0.873, where the Number of long sight lines equal zero, Proportion of street wall (within study side) is 85% Proportion of street wall (opposite side, beyond study area) is 85%, Proportion of sky (ahead, beyond study area) is 20%, Proportion of sky (across, beyond study area) is 15% as shown in Fig 6 .By reviewing the physical features that affect the Enclosure, these streets achieves these factor which proves the validity of the statistical analysis.


Fig 4. AL Moez


Fig 5. Champollion St


Fig 6. Gohar EL Qaeed St

6.3 Human Scale

The result of statistical analysis showed that the best streets in terms of Human Scale is AL Moez St with score of one, where the Number of long sight lines equal zero, Proportion of windows at street level (within study side) exceeds 90%, Proportion of active uses (within study area) exceed 100% and Average building heights (within study area side) does not exceed 8 meters. It also has space outdoor furnishing elements, lighting units that consider human factor, excessive details in buildings and some hawkers that enhance the human scale.The next street in the ranking is a Gohar El Qaeed St with score of

0.987, where the Number of long sight lines equal zero, Proportion of windows at street level (within study side) exceeds 70%, Proportion of active uses, within study area) exceeds 95%, Average building heights (within study area side) does not exceed 9 meters and the Number of miscellaneous street items (within study area side) exceeds 40 elements, All of these physical features emphasize the human scale of the street . the third street in the ranking is Ibrahim Al Lakani St with score of 0.947, where the Number of long sight lines equal one, Proportion of windows at street level (within study area side) exceeds 80%, Proportion of active uses, within study area) exceeds 76%, Average building heights (within study area side) does not exceed 12 meters and the Number of miscellaneous street items (within study area side) exceeds 40 elements, All of these physical features emphasize the human scale of the street determining that this street comes in the third rank.

6.4 Transparency

The result of statistical analysis showed that the best streets in terms of transparency is EL-Moez St with score of one, The street is characterized by being a commercial street on the level of the ground floor, where the Proportion of windows at street level (within study area side) is 90% as shown in Fig 7, the Proportion of street wall (within study area side) is 98%, and the Proportion of active uses (within study area side) reaches 100%.The next street in the ranking is Ibrahim Al Lakani St with score of 0.930, The street is characterized by being a commercial street also as shown in Fig 8 ,where the Proportion of windows at street level (within study area side) is 80%, the Proportion of street wall (within study area side) is 93%, and the Proportion of active uses (within study area side) reaches 78%.The third street in the ranking is Kasr El-Nile St with score of 0.901, The street is characterized by being a commercial street also as shown in Fig 9, where the the Proportion of windows at street level (within study area side) is 80%, the Proportion of street wall (within study area side) is 80%, and the Proportion of active uses (within study area side) reaches 95%. By reviewing the physical features that effect the Transparency found it is available in these streets which proves the validity of statistical analysis.

Fig 7.AL Moez St

Fig 8. Ibrahim EL-Lakani St

Fig 9.Kasr El-Nile St

6.5 Complexity:

The result of statistical analysis showed that the best streets in terms of Complexity is Gameat AL Dewal Al Arabeya St with score of one, where the number of buildings (both sides, beyond study area) is70 buildings, the Presence of outdoor dining (within study area side) is zero , the Number of primary building colors (both sides beyond study are) is two as shown in Fig 10, the Number of accent colors (both sides beyond study area) is 23 colors, the Number of pieces of public art (both sides, within study area) is zero, and the Number of pedestrians (within study area side) is 857 person .The next street in the ranking is Kasr EL-Nile St, where the number of buildings (both sides, beyond study area) is 14 buildings, the Presence of outdoor dining (within study area side) is zero, the Number of primary building colors (both sides beyond study are) is two as shown in Fig 11, the Number of accent colors (both sides beyond study area) is 3 colors, the Number of pieces of public art (both sides within study area) is zero, and the Number of pedestrians (within study area side) is 85 person. The third street in the ranking is Abbas El Akkad, where the number of buildings (both sides, beyond study area) is 26 buildings, the Presence of outdoor dining (within study area side) is zero , the Number of primary building colors (both sides beyond study are) is two as shown in Fig 12, the Number of accent colors (both sides beyond study area) is 5 colors, the Number of pieces of public art (both sides within study area) is zero, and the Number of pedestrians (within study area side) is 620 person. The physical features that effect the Complexity achieved with large extent in these streets, which is proves the validity of statistical analysis.

Conclusion:

From the previous study, a methodology for evaluating the walkability of Cairo streets was derived; the opinions of experts were avoided while the weights of physical features and qualities of urban design were determined without the interference of the human factor using Cook et.al, 1996. The research got some different values for each street to arrange them according to their walkability level.


Fig 10. Gameat AL Dewal St


Fig 11.Kasr EL-Nile St


Fig 12.Abbas El Akkad St

- The statistical study results were revised and proved which resulted in arranging Cairo streets according to their level of walkability, physical features and qualities of urban design in these streets which verifies the used methodology in the analytical statistical study using BOD model for evaluating the walkability in Cairo streets. This methodology will be usable in evaluating any street in Cairo which provides decision makers with a tool to take suitable decisions to improve walkability in the Egyptian urban environment.
- Streets that has historical buildings, buildings of architectural value or buildings with architectural styles are the preferred streets for walking in Cairo such as, el Moez street and Gohar EL Qaeed St street in historical old Cairo, Ibrahim EL-Lakani and Kasr EL-Nile street.
- The walkable preferred streets in Cairo are featured with commercial and mixed uses.
- People in Cairo prefer walking in Cairo city in streets that consider human scale.
  This is why its recommended to provide commercial and mixed used in building and designing new urban environments in Egypt, as well as using architectural styles and considering human factor to encourage people to walk.

Future print of research:

- There are a lot of statistical approaches to be used in the reference OECD 2008, and some other approaches to be analyzed and confirmed with the suggested approach in this research.
- The research linked the Macro level with Micro level but information about Macro level were not available on the level of the streets in Egypt, so in future studies it is recommended to collect these missing data and link them with the data from the research in order to get more holistic results.

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