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EVALUATING FOUR ELEMENTS FOR QUALITY OF OPENSTREETMAP BUILDINGS LAYER

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Abstract- OpenStreetMap (OSM) is a well-known volunteered geographic information (VGI) initiative whose goal is to create a free-world map. The completeness and quality of OSM data have high differences due to the diversity of data sources and volunteers' background. However, due to the wide range of OSM applications, researchers have focused greatly on investigating and determining its quality. OSM quality assessment determines whether OSM data are accurate enough for precise work or research. The OSM databases are currently considered nearly complete in various cities or countries, and are widely utilized as an alternative to authoritative data. In this research, the quality of OSM buildings dataset was evaluated by comparing them with reference dataset in two different study areas within Baghdad city. Four types of quality indicators have been identified (shape similarity, attribute accuracy, features relationship, and orientation consistency). The outcomes revealed that the orientation for OSM strongly differs from the orientation of reference data, while the shape accuracy is highly similar between the two datasets. Concerning the attribute accuracy, the findings showed that the OSM attribute table has poor data and lacks details for both study areas.

Keywords: OpenStreetMap, Volunteered Geographic Information (VGI), Building Data, Data Quality.

1. INTRODUCTION

Volunteered Geographic Information (VGI) is free geographical data provided by "volunteers" such as geographers and citizens who provide geo-referenced data. Because VGI may be created by any person, there is no guarantee of quality or creator's awareness. VGI sometimes lacks data explaining its source or quality, making it impossible for users to measure how accurate the data is. OpenStreetMap (OSM) is a common type of VGI data with many contributors [1].

It is an accessible global map that gathers data from the public. OSM enables everybody to make or update features like roads, buildings, and points of interest. In terms of gauging quality, there are no assertions that can be made regarding the experience of contributors [2]. The OpenStreetMap (OSM) program started in 2004, and it initiated a new concept for Geodata collection and usage. It is rapidly expanding as a source of geographical data since 2004 due to the growing popularity of GPS devices among private individuals, as well as the accessibility of web-based mapping platforms that provide high-resolution Ortho-photographs. This enables volunteers to contribute to the OSM project by digitizing objects such as roads, buildings, and land use. Thousands of amateurs became able to collect and upload data to OSM service. Many web users can access OSM data for free. Users can use the OSM sources to browse any part of a world map and download data for specific parts [3].

Several metrics have been used to measure the OSM spatial data quality. Many criteria of data quality are mentioned by the International Organization for Standardization (ISO) in their standard 19157, including thematic accuracy, Relationship of building accuracy, and shape exactness. While these data quality elements may be used for many different types of geographical data. Methods was proposed to quantify such elements of quality for OSM data [4]. However, their techniques may be complex for the average person or organizer as they include complicated calculations and highly specialized programs. Information of OSM quality is particularly important for a variety of reasons. For example, the potential for integrating various datasets that may be utilized for further GIS research and applications, as well as the expansion of decision-making processes based on spatial data [5, 6]. In recent years, there has been an increasing amount of literature on OSM data quality. For instance, an assessment was presented for the OSM building database quality in Quebec, Canada [7]. The quality indicators which have been evaluated were attribute accuracy, completeness, shape accuracy, and positional accuracy.

The official data utilized in this work was provided from Donnees Quebec which is an open collaborating data center for Quebec. The researcher comes to a conclusion that there is still a need more time until the OSM database represents Canada completely. In addition, the completeness and spatial accuracy of OpenStreetMap buildings in north Italy was assessed [8]. They used Regional Topographical Database (DBT) as reference data to evaluate OSM data.

An automatic algorithm has been used to assess the competence, positional accuracy, relationship of building features, and shape comparison. This assessment shows that quality of OSM buildings is approximately equivalent to the authoritative technical map on a scale of 1:5000.

An investigation of OSM dataset completeness has proceeded in different approaches using object-based and unit-based techniques. Taichung and Taipei urban districts in Taiwan were chosen to be tested. The conclusion was that the OSM data does not display the entire current data in the country [9].

In this paper, the investigation was concentrated on comparing the quality of OSM building features within selected parts of Baghdad, Iraq, to the building dataset graciously digitized from satellite images, which was chosen as reference data [17]. Four indicators were used to determine the quality of the buildings that were retrieved from OSM and reference data for the assessment. In order to evaluate the various quality aspects, corresponding features from the two data sets were compared.

2. STUDY AREA AND DATASETS

Two areas were selected to be assessed in Baghdad, the capital city of Iraq. The first area was Al-Karrada city which is located in the heart of Baghdad and covering an area of approximately 12 Km^2. The second area was Al-Rasheed in the rural area of Baghdad, covering 16 Km^2. The reference data, the OSM data was changed into UTM projection, Zone 38 N using Arc Map 10.8 software. The OSM polygon features contain twenty layers: waterway, historic, location, power, aero way, barrier, building, man-made, shop, amenity, highway, railway, aerial way, leisure, military, tourism, natural, land use, boundary, geological. In this research the quality of building layer has been evaluated because it contains all polygon features that represent buildings in OSM data.

The reference data was created manually by screen digitizing process. The reference data consists of a digital vector map produced by digitizing the building features from satellite images for the two study areas using Arc Map 10.8 software. The satellite images obtained from WorldView-3 satellite, and their resolution was 0.3 m with no cloud cover. The digitizing process initiated with creating a new geodatabase file in Arc Catalog, and creating a new feature dataset named "building". Then, the coordinates system (WGS84) and the projection type (UTM, Zone 38 N) have been selected in order to create a polygon feature class. Table 1 illustrates the number of buildings for each study area.

Table 1. Number of buildings in OSM and reference datasets

Study area	No. of Buildings in reference data	No. of Buildings in OSM data
Al-Rasheed	7384	7786
Al-Karrada	10256	10767

2.1. Measures to Assess OSM Data

This work concentrated on analyzing the quality components of OSM datasets, such as shape similarity; orientation accuracy; features relationship; and attribute consistency with respect to the authoritative or reference source. Before proceeding with the quality assessment, OSM's polygons should be matched with their corresponding polygons in the reference data.

The matching procedure includes intersecting the two data sets, and the overlapping area percentage between the two data sets can be used as a criterion for finding the matching polygons [4]. The overlapping area between the reference and OSM feature must be 30% of the reference polygon's area. When the overlapping area is less than 30%, the two features are considered not corresponding; it's treated as an outlier and will be neglected. On the other hand, if the overlap of any two features in different dataset equal or more than 30%, they can be considered correspondent features [10].

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3.1. Relationship of Building Features

The first data quality indicator was the relations between the features of datasets which has been achieved by classifying the correspondent buildings. It's a complicated relationship between reference and OSM features due to the inaccuracies that may happen through OSM data creation. The OSM polygon exemplifies the roofing, not the footprints, so it may include a few displacements. The OSM buildings data may be near to the reference buildings, such as a generic representation for the reference buildings with a positional offset [11]. Following presents a description for the relationships between the reference and the OSM data:

- 1:1 - When the reference building is matched with one OSM building, this is the only situation where both datasets are entirely complete.
- 1:0 - This state results when the reference database matches no polygon in the OSM data.
- 1:*n* - When a building in the reference dataset matched with several buildings in OSM data.
- 0:1 - This case represents a building within OSM that does not correspond to any polygon in the reference dataset.
- *n*:1 - In this case, several buildings within reference data correspond to one building in OSM data.
- *n*:*m* - In this case, several buildings in reference database are matching with several buildings in OSM data.

3.2. Shape Accuracy

The main issue with shape accuracy of OSM data is that the polygons are not mapped with an equal level of detail as the authoritative database. In addition, errors may be introduced into digitizing process due to the shortage of geographic knowledge of the volunteers. Hence, it is important to examine how comparable the shapes of OSM buildings are to the shapes of the buildings in the authoritative or reference datasets. In this research, three methods have been adopted to evaluate the shape accuracy of OSM buildings. The first method is based on the area ratio, which is a simple calculation to compute how often the area of the OSM polygon is bigger or smaller than its corresponding polygon [12].

$$A_{ratio} = \frac{A_{OSM}}{A_{ref}} \quad (1)$$

where, A_{ratio} represent the area ratio, A_{OSM} represent the area of OSM polygon, and $A_{ref.}$ represent the area of reference polygon.

The shape accuracy of OSM buildings was also assessed using compactness metrics. It is an indicator of the deviation of a polygon from a standard feature. The two common methods usually used to compute the compactness are the reock-scores and the Convex Hull scores. The reock-score represents the ratio of feature area to its minimum bounding circle [13].

$$R(d) = \frac{A_d}{A_c} \quad (2)$$

where, $R(d)$ is a reock-score for a polygon, A_d represents the area of the polygon, and A_c represents the area of the minimum bounding circle of d. The Convex Hull score method is the ratio of polygon area to its convex hull. Each score represents a numerical outcome within the range (0, 1). The score 1 is an indicator that the polygon is optimally shaped, while any score near 0 is considered non-optimal. The definition of the Convex Hull score formula is [13]:

$$CH(d) = \frac{A_d}{A_h} \quad (3)$$

where, $CH(d)$ is the polygon compactness, A_d represents the area of the polygon, and A_h represents the convex hull of polygon. The Elongation is the third way to compute the shape accuracy. It can be expressed as follows [12]:

$$E = 1 - \frac{W}{L} \quad (4)$$

where, E represents the elongation, L and W represent the height and width of the smallest rectangle including the polygon's shape; when elongation is equal to 1, the shape is close to a line; when elongation is equal to 0, the shape is close to a circle.

3.3. Attribute Accuracy

The attributes provide significant descriptive information about spatial features. Therefore, attribute accuracy is an important aspect of data quality. While expert users may pay great attention to them, many contributors are likely unaware of the idea of "attribute quality" while developing features. The OSM attributes are listed as tags, while no rules are required for recording these tags. The important field of the attribute is the building name.

However, the objective of attribute assessment is to figure out the accuracy of these names [7]. The first examination will reveal the nature of the business for which commercial buildings are used. The second test will determine whether or not the building type has been identified, instead of simply stating "yes". The final test will determine whether or not the buildings have been given names. Named buildings are often industrial, governmental, or residential. These three assessments provide a complete picture of the attributes or the thematic accuracy [1].

3.4. Orientation Accuracy

To estimate the orientation of the buildings, minimum bounding rectangle geometry was created for all reference buildings and OSM buildings. The direction of the longer side of each bounding polygon was computed clockwise from the north in decimal degrees. The orientation variation between each matching reference and OSM building couple within a 1:1 relationship was determined [11].

4. TWO SAMPLES T-TEST

In this research, statistical analysis was used to value the error reference and test data by using the two-sample t-test. The independent two-sample test was used to determine whether population means differed significantly from one another using means from a randomly drawn sample. The null hypothesis can be accepted or rejected using two values: p-value and t-critical. The p-value represents an index to accept or reject the null hypothesis. The null hypothesis considers the difference between reference and OSM data to be equal to zero, while the alternative hypothesis considers the difference between two datasets not equal to zero.

The null hypothesis stated as (H_0: $\mu_1 = \mu_2$). Where, μ_1 is the mean of the first study area datasets and μ_2 is the mean of the second study area datasets. On other hand the alternative hypothesis stated as (H_1: $\mu_1 \neq \mu_2$). The critical value acquires from the distribution, it cannot be rejected if the t-value is fall within the non-rejection range [14].

A boxplot graph was used to represent the numerical statistical value; it represents data depending on the following summary: Q_1 represents the first quartile or 25% of the box plot's lower line, Q_2 represents the median or 50% of the box plot's central line and Q_3 represents the third quartile or 75% of the box plot's upper line. Whisker is the line that extends from the right of the box to the maximum point of data, while the lower whisker is the line that extends from the left of the box to the minimum point of data [15].

5. RESULTS AND DISCUSSION

The results road relationships are shown in Table 2. Around 39% of the buildings in reference data and OSM datasets belong to the 1:1 relation class in both study areas. A small portion of buildings within 1:0 ratio was detected in the reference dataset, suggesting that they were either missing by OSM users or were not classified as buildings. This assessment considers that the outline of all buildings can be recognized in based image that used when the OSM building have been digitized. Furthermore, buildings in the reference dataset are heavily represented in the 1:*n* class when one building in reference data represented by multiple buildings, also a comparable ratio found with *n*:1 class when multiple buildings in reference data represented by one building in OSM data. A small portion of buildings detect within 0:1 relation class; these buildings do not exist in reality, or they were different features digitized as buildings by contributors. The relation class evaluation indicates that the OSM does not have a high degree of quality. The quality of OSM data increases as the ratio of buildings within the 1:1 class increase. In some countries such as Singapore, the relation class 1:1 has a ratio of 95% of the OSM buildings data [9].

Table 2. Relation classes for the two-study areas

Relations	Al-Karrada	Al-Rasheed
1:0	10.19%	4.26%
1:1	36.60%	39.26%
n:1	53.10%	45.86%
1: *n*	56.93%	51.99%
0:1	7.38%	8.25%

The shape accuracy can provide an idea of how comparable the buildings in OSM are to the corresponding buildings in the real world. The first indicator for shape similarity was the area ratio, which is easy to compute and is a basic criterion. By applying Equation (1), the area ratio was computed for both study areas and the results were presented in Table 3. A boxplot graph was generated to represent the differences in area ratio between Al-Karrada and Al-Rasheed study areas using a Two-Sample T-Test analysis as Figure 1.

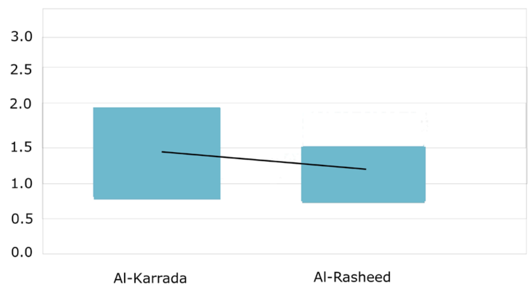

Figure 1. Area ratio distribution for the two study areas

Table 3. The area ratio comparison

City	No. of building	Mean	StDev
AL-Karrada	5982	1.77	2.12
AL-Rasheed	3156	1.41	1.92

According to the information represented in the Figure 1, the outcomes of Al-Karrada city were $Q_1 = 0.925$, the median = 1.278, $Q_3 = 1.995$, and the whiskers 0.303, 3.590. While for Al-Rasheed region the results showed that the $Q_1 = 0.893$, the median was 1.140, $Q_3 = 1.530$, and the whiskers were 0.309, 2.485. The line extending between the two data shows that the median of the two datasets falls at the same level. This indicates that the two study areas have nearly equivalent levels of shape accuracy. Table 4 demonstrates that the mean area ratio for the two study areas is greater than one. This means that the OSM building has a good area ratio and appears to have a slightly larger area than the corresponding building in the reference data.

The compactness was the second approach used to assess shape similarity. It is the ratio of the building's area to its convex hull. The corresponding building can be described as similar if the reference and OSM building have the same compactness value. However, compactness does not imply that the two polygons are identical; rather, it indicates how they are similar as Table 4.

Table 4. Compactness assessment for the two-study areas

City	No. of building	Mean Compactness OSM Data	Mean Compactness ref. Data	Mean of Compactness ratio	StDev of Compactness ratio
Al-Karrada	5982	0.9752	0.9323	0.9776	0.0914
Al-Rasheed	3156	0.9726	0.9827	0.9830	0.0930

The mean compactness ratio is almost equal to 1 as Table 4. It indicates that the OSM and reference data have a high compactness ratio in the two study areas. Also, the mean compactness value for OSM buildings is nearly similar to the reference buildings compactness. It means that the compactness of the two databases is almost the same as Figure 2.

Figure 2. The compactness differences for the two study areas

Figure 2 represents the differences in compactness for the two datasets. According to the information represented in the Figure 4, Al-Karada data $Q_1 = 0.931$, the median = 0.980, $Q_3 = 1.015$, and the whiskers 0.804, 1.142. While for the Al-Rasheed $Q_1 = 0.945$, the median was 0.992, $Q_3 = 1.011$, and the whiskers were 0.848, 1.109. The line extending between the two data shows that the median of the two datasets falls at the same level. This analysis revealed that the two study areas have nearly the same degree of shape accuracy. The compactness assessment revealed that the OSM buildings that corresponded to the reference data have a high shape similarity in both study areas. The elongation was the third procedure that utilized for shape similarity measurement, which was calculated for each pair of matched polygons. The width and length required for elongation obtained by the minimum bounding geometry. Table 5 shows that the variations in elongation are very small between the authoritative and OSM data.

Table 5. The results of elongation assessment

City	No. of building	Mean elongation of Ref. data	Mean elongation of OSM data	Mean of the diff. in elongation	StDev. of the diff in elongation
Al-Karrada	5982	0.439	0.454	0.118	0.101
Al-Rasheed	3156	0.468	0.566	0.124	0.118

Figure 3 shows the differences in elongation for the two datasets. Based on Figure 6, the outcomes of Al-Karrada city showed that the Q_1 = 0.0389, the median = 0.0896, Q_3 = 0.172, and whiskers of 0.0, 0.372. While the results of Al-Rasheed indicated that the Q_1 =0.0379, the median =0.0887, Q_3 =0.18287, and whisker 0.00009, 0.3999. The line extending between the two data shows that the median of the two datasets is almost at the same level. The outcome of this analysis indicated that the two study areas have almost the same degree of shape accuracy. The results of the elongation assessment also showed that the variations of the differences in elongation are very small which indicated that the shape similarity of the OSM building with its corresponding reference building is high.

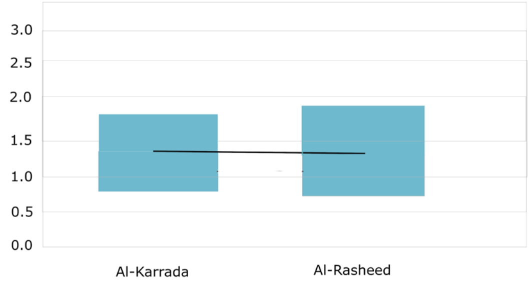

Figure 3. The distribution of elongation differences for two-study area

The attributes of buildings data are important to identify the buildings types and their locations. The main subject to evaluate the attribute data is the name of the features which is quite empty in most fields of OSM attribute table, and only a few buildings have a description in the two study areas. This indicates that the attribute accuracy in both study areas is poor; however, Al-Karrada (urban area) seems to have more attribute information than Al-Rasheed city (rural area), as shown in Table 6.

Table 6. The results of attribute assessment for the two study areas

Attribute Details	Al-Karrada	Al-Rasheed
Building	75	0
Amenity	26	15
Shop	3	0
Historic	1	2
Man Made	4	0
Leisure	0	3
Total ratio	1%	0.256%

When inspecting the information of field "building" in the attribute table of OSM data of two study areas, it was noticed that there was no detailed information other than "yes" was inputted in this field.

Furthermore, for the two study areas' data, none of the buildings were given a specific name. Other information observed in various fields of both study areas' attributes are illustrated in the Tables 7 and 8. These tables show the descriptions of building types given by the contributors, as well as the number of buildings with the same descriptions. The numbers of buildings described in these tables are insufficient compared to the massive amount of OSM information.

Table 7. The results of attribute description assessment for Al-Karada study areas

Field	Description	No. Of Building
Amenity	Events Venue	1
	Theatre	1
	Library	1
	Place Of Worship	11
	Library	2
	Bank	1
	Fast Food	1
	Restaurant	2
	Cafe	1
	Conference Centre	1
	Post Office	1
	College	1
	Religious	1
	Sport Center	1
Historic	Castle	1
Shop	Car	1
	Mall	1
Man Made	Storage Tank	1
	Water Tower	1

Table 8. The results of attribute description assessment for Al-Rasheed study areas

Field	Description	No. of Building
Amenity	School	11
	University	2
	Place of Worship	2
Historic	Park	1
	Sports Centre	2
	Swimming Pool	1

The attributes of OSM data were added based on volunteer's knowledge and experience. Hence, it can be predicted that the OSM buildings with correct attributes were mostly added by volunteers who may have the local expertise and were eager to improve the OSM quality in those areas. For the orientation assessment, the mean absolute and standard deviation of orientation for the two study areas are presented in Table 9. It is clear that the orientation of building features in Al-Karrada city is higher than other study area. This indicates that OSM's orientation quality for Al-Karrada is poor; nevertheless, the orientation quality of OSM buildings in rural area (Al-Rasheed) is extremely good and better than in urban areas. Figure 4, shows the distribution of the differences in orientation with a boxplot diagram.

Table 9. The results of orientation assessment for two study areas

City	No. of Building	Mean	StDev
Al-Karrada	5982	53°48'	43°30'
Al-Rasheed	3156	1°54'	1°24'

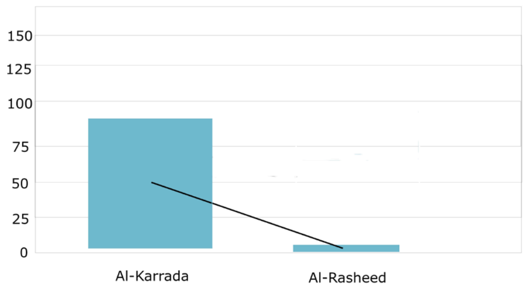

Figure 4. The orientation differences for the tow study areas

According to Figure 4, the results of Al-Karrada city were Q_1 = 12.3, median = 50.8, and Q_3 = 87.5, whereas for Al-Rasheed Q_1 = 1, median = 2.1, and Q_3 = 4.6, which indicating a significant difference between the two datasets. Al-Rasheed data provide good results and small differences in orientation, as well as a better data distribution than Al-Karrada, with whiskers set to 0.0, 9.7 for al-Rasheed and 0. 178.1 for Al-Karrada respectively. The extending line between the two medians shows that there is a huge variation in orientation accuracy between the two datasets.

In the orientation assessment, the maximum absolute difference extracted was 178°. This large difference is expected due to the minimum bounding geometry that is used to evaluate the orientation of OSM buildings data. When observing the reference buildings in the two study areas noticed that they are most often rectangular in shape and have a long side. Some of the buildings are square in shape. The square buildings in OSM and reference data have a wide difference in orientations. The large variation in orientation most occurs due to the shapes error that was recorded when digitizing the OSM buildings by volunteers. A number of buildings were discovered that are perfectly square and have been mapped with varying angles in a VGI dataset by untrained contributors [15]. As a result, a square-shaped building in OSM with minor differences in length or angles may be recognized by the program as a rectangular building. That is the main reason for the high differences in orientation.

6. CONCLUSION

The aim of the present research was to assess the quality of OpenStreetMap buildings data for two study areas inside Baghdad city. Four quality indicators were examined using several geospatial analytic processes. The overall buildings quality of OSM was poor; this could be attributed to a variety of factors, such as contributors being amateurs, lacking geographic expertise, or failing to pay attention to the smallest details when creating features. However, the shape accuracy evaluation showed a high degree of similarity for the matching polygon in the two study areas. Although the orientation assessment showed that the OSM buildings for the rural area (Al-Rasheed) generally have the same dominant direction as the corresponding buildings in the reference dataset. For the urban area (Al-Karrada), the assessment showed higher differences in the orientation of the two datasets.

The attribute accuracy of OSM buildings is far from perfect, with only a few fields being correctly filled. It is suggested that future contributions pay more attention to attribute information, which is an important aspect of geographical data. Most buildings in both study areas have a 1:*n* relation class, which means that a building in the reference dataset was matched with a number of buildings in the OSM data, assuming that users were either unable to distinguish most of the individual buildings from the base images in OpenStreetMap or did not pay attention to the crowded residential quarter. The overall quality of OpenStreetMap building data in Baghdad is not acceptable for precise work or research.

However, it could be used for different applications which no need high accuracy, such as Map Factor Navigator and Locus Map applications. Map Factor is an application that provides OSM maps for users to freely install on their devices and use while traveling without the requirement of an Internet connection. This application map is updated every month. Furthermore, Locus Map is an application for navigation services that provide online and offline GPS ability. It is used for outdoor activities such as biking, and hiking. Aside from its leisure activity use, the application is also used by experts, such as rescue squad teams.

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