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Mapping Gated Communities:
An Empirical Assessment of Wikimapia Data Quality

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ABSTRACT

The widespread proliferation of different types of volunteered geographic information (VGI) is noteworthy as is its potential application to urban studies. However, questions of data quality still remain. In some parts of the Middle East, gated communities have proliferated rapidly, but relatively little is known about their extent or spatial distribution. This case study of gated communities in the state of Bahrain assesses the quality of Wikimapia, a form of VGI, in accurately identifying elements of urban structure (e.g., gated communities) in an urban context from the Global South. Wikimapia demonstrated high levels of positional accuracy and relatively high levels of attribute accuracy. Identifying the locations of gated communities provides a foundation from which other research questions about segregated housing, fragmentation, and socioeconomic polarization can be addressed. These results highlight Wikimapia's potential as a data source for urban research, particularly in data-poor and non-Western/Northern contexts.

KEYWORDS

Accuracy Assessment, Bahrain, Middle East, Volunteered Geographic Information (VGI)

INTRODUCTION

Socioeconomic polarization and residential segregation are two trends affecting cities around the world (Daskalova and Slaev, 2015; Michelini and Pintos, 2016; Glebbeek and Koonings, 2016; Fahlberg and Vicino, 2016; Ma, Li, & Zhang, 2018). Cities in both the Global North and the Global South are impacted by socioeconomic inequality and uneven development, but the ways in which these dimensions manifest themselves is contextually dependent. The growth of particular forms of housing (e.g., slums, gated communities, social housing, affordable housing) is one of several indicators that can be monitored to shed light on processes of urban fragmentation and socio-economic polarization. Within the urban studies literature on these topics, smaller cities, particularly in the Global South, have been relatively overlooked; larger cities tend to receive a disproportionate amount of attention.

The Arab Gulf states have some of the world's highest urbanization rates; socioeconomic polarization and stratification are major trends in Gulf cities (Glasze, 2006; Khalaf, 2006; Elsheshtawy, 2008; Smith, 2010). The morphology of Gulf cities has evolved in a variety of ways (Ben Hamouche, 2004); one notable change is the increasing prevalence of gated communities for white-collar professionals as part of the spectrum of residential options. However, precise information about their number or spatial distribution of these types of gated communities is publicly unavailable.

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Understanding the number and location of these types of housing is a critical step toward further studies of socioeconomic polarization and residential segregation in the Gulf city.

The emergence of new data sources, such as Big Data and Volunteered Geographic Information (VGI), provides novel opportunities and challenges for the study of these trends in contemporary cities worldwide (Arribas-Bel, 2014; Batty, 2016), but significant questions remain regarding the quality of VGI (Fonte et al., 2017; see also the special section edited by Basiri, et al. (2019) in the International Journal of Geographical Information Science).

The aim of this paper is to test the utility of Wikimapia, a form of VGI, as a data source for research in urban studies, by assessing its quality in identifying particular elements of urban structure. Specifically, this paper assesses Wikimapia's data quality by analyzing its accuracy in mapping the locations of gated communities in the Bahraini case, which involves a smaller city and a relatively data-poor context. This paper addresses three interlinked research questions:

1. What is the positional accuracy of Wikimapia in identifying specific elements of the built environment?
2. What is the attribute accuracy of Wikimapia in identifying specific elements of the built environment?
3. What types of errors are most prevalent in Wikimapia in this specific context?

The practical question addressed in this case study is whether the locations and spatiality of gated communities in a data-poor context can be accurately determined using VGI. This case study focuses on gated communities, but the results have broad implications in other contexts. This paper contributes to a larger awareness of the accuracy of Wikimapia, and thus the utility of various forms of VGI for urban research, in other data-poor contexts. Given the preponderance of research on VGI in North American and European contexts, empirical work from less studied places (e.g., smaller cities and countries that are understudied) provides a valuable insight into how VGI can be of value in urban research.

GATED COMMUNITIES

The presence of gated communities is simultaneously a driver and an outcome of social inequality and segregation in the city (Blakely & Snyder, 1997; Gooblar, 2002; Maher, 2004; Miller & Blevins, 2005). Research based in the United States and Europe indicates that demand for gated communities is driven by security, real or perceived, sense of community, and prestige (Fowler & Mangione, 1986; Atlas & LeBlanc, 1994; Lang & Danielsen, 1997; Wilson-Doenges, 2000; Leisch, 2002; Low, 2003). Gating is not only a phenomenon of the Global North; countries across the Global South are also sites for this kind of development (Bagaeen & Uduku, 2015; Tedong, Grant, & Aziz, 2015; Borsdorf, Hidalgo, & Vidal-Koppman, 2016; Zhao & Zhang, 2018).

Gated communities have been studied in a variety of Middle Eastern countries, including Israel, Egypt, Lebanon, and Saudi Arabia (Kuppinger, 2004; Glasze, 2006; Geniş, 2007; Alaily-Mattar, 2008; Rosen & Razin, 2008; Güzey, 2014; Blander, Moser & Avni, 2018; Tanulku, 2018). This study analyzes gated communities for white-collar professionals (known locally as compounds[1]) in Bahrain. Gated communities in the Middle East, particularly those present in the Gulf, resemble their counterparts in the North American context to a certain degree. For example, differences in socioeconomic status are a main driver of residential segregation. Leichenko and Solecki conceptualize residents of gated communities in Cairo as members of a transnational capitalist class who have "the financial means to segregate themselves in gated communities and suburban enclaves that are away from urban cores" (Leichenko and Solecki, 2008, p. 20). However, there are some notable differences between gated communities in the Gulf and in North America: security and sociocultural differences between

residents and the surrounding society are some of the main reasons why residents choose to live in gated communities in the Gulf. Also, the historical roots of gated communities in the Gulf are unique: the compounds that are the focus of this study trace some of their roots to the housing that was built, as Bahrain's petroleum-exporting economy first developed, for workers in the petroleum sector.

Volunteered Geographic Information (VGI)

User-generated content (UGC) refers to data created and shared by users; VGI is a subcategory of UGC with explicitly spatial characteristics. A user's photograph uploaded to the photo-sharing website Flickr is an example of UGC; if the same photograph includes a geotagged location it is an example of VGI. VGI's most novel feature is its crowd-sourced, bottom-up approach. VGI is a highly heterogeneous category; scholarship on UGC and VGI has examined a number of sources including OpenStreetMap (OSM) (Haklay, 2010; Zhang et al., 2015; Quinn & Yapa, 2016), Flickr (Schlieder & Matyas, 2009; Jankowski et al., 2010; Figueroa-Alfaro & Tang, 2016; Sun et al., 2016), and Wikimapia (Ahmouda & Hochmair, 2017; Bittner, 2017; Ballatore & Arsanjani, 2018).

As it contributes to new types of knowledge production, VGI can provide data in a range of applications and areas, including environmental monitoring (De Longueville, Ostländer, & Keskitalo, 2010; Conners, Lei, & Kelly, 2012; Upton et al., 2015), disaster response and relief (Goodchild & Glennon, 2010; Zook et al., 2010; Hung, Kalantari, & Rajabifard, 2016; Kusumo, Reckien, & Verplanke, 2017), crime (Tompson et al., 2014), decision making (Rinner, Keßler, & Andrulis, 2008), and public health (Cinnamon and Schuurman, 2013; Langley, Messina, & Grady, 2013; Griffin & Jiao, 2015). Relatively more recently, a small number of studies have demonstrated VGI's utility in studying urban issues, examining topics as varied as the extraction of land use patterns (Hagenauer & Helbich, 2012; Vaz & Arsanjani, 2015), slum upgrading (Hachmann, Arsanjani, & Vaz, 2018), urban forest management (Foster & Dunham, 2015), participatory planning (Adams, 2013), functional zones (Johansson, 2016), socio-spatial inequality (Shelton, Poorthuis, & Zook, 2015), mobility patterns (Salas-Olmedo & Quezada, 2017), and the extraction of points of interest from user annotations (Mummidi & Krumm, 2008; Jiang et al., 2015; Feick & Robertson, 2015).

The key feature of VGI, the fact that it is volunteer-generated, is simultaneously a key limitation, as concerns arise about the quality of data provided by volunteers whose skill and knowledge are unknown. Research on VGI data quality has examined a range of methods (Flanagin & Metzger, 2008; Senaratne et al., 2017; Fonte et al., 2017; Langley et al., 2017) and approaches (Goodchild & Li, 2012; Barron, Neis, & Zipf, 2014; Antoniou & Skopeliti, 2015; Fonte et al., 2017), as well as assessments of specific areas and applications (Girres & Touya, 2010; Haklay, 2010; Zielstra & Zipf, 2010a; Zielstra & Zipf, 2010b; Fonte et al., 2015).

Assessments of VGI data quality can examine a variety of aspects, including positional accuracy, attribute accuracy, logical consistency, currency, completeness, and lineage. The two key aspects of data quality assessed in this study are positional accuracy and attribute accuracy. Positional accuracy is defined as the accuracy of coordinate values (van Oort, 2006), or how well an object's coordinate value in the database relates to the corresponding reality on the ground (Haklay, 2010). Attribute accuracy is defined as the accuracy of all attributes (other than positional and temporal attributes) in a spatial dataset (van Oort, 2006). This project also draws on accuracy assessments in other non-VGI contexts, including public participation GIS (Brown, 2012; Brown, Weber & de Bie, 2015) and post-disaster remote damage assessments (Westrope, Banick, & Levine, 2014).

As this study includes an assessment of positional accuracy and moves forward to address attribute accuracy, it aligns with calls for VGI research to evaluate measures of spatial data quality besides positional accuracy (Haklay, 2010) and broader trends toward research on attribute accuracy (Ye et al., 2011). As it directly verifies VGI against actual features, this paper differs from the most frequently used approaches to the assessment of VGI accuracy, which compare VGI with reference sources (see, for example, Girres & Touya, 2010; Haklay, 2010; Jackson et al., 2013; Foody et al.,

2013). The ground-truthing approach taken here is relatively less common due to its costs in terms of access, time and resources (see Westrope, Banick, & Levine (2014) for a notable exception).

This study examines the data quality of a particular form of VGI, specifically with respect to identifying specific elements of urban structure. As such, the study is concerned with *errors of commission* – when a feature is mistakenly included in the evaluation dataset. Ascertaining the total number or locations of gated communities in Bahrain is not the aim of this study; the assessment of *errors of omission* – when a feature is mistakenly omitted from the evaluation dataset – is beyond the scope of this research. This study refers to several metrics of spatial data accuracy more commonly used in other domains, such as remote sensing: *User's accuracy* measures errors of commission by determining the percentage of all identified items that have been identified correctly. Errors of omission are measured by the metric *producer's accuracy,* which identifies the percentage of correctly classified items as a percentage of the total (possible) items that belong in that category.

METHODOLOGY

Study Area and Subject of Study

The *study area* is the Kingdom of Bahrain, in the Persian/Arabian Gulf. Reflecting trends in the Gulf, Bahrain is highly urbanized, with an urbanization rate just over 89 percent (United Nations, 2018). Rapid urbanization has led to many transformations including loss of agricultural land, coastline changes as a result of dredging and land reclamation, and suburbanization. The *study subjects* are gated communities for white-collar professionals. The proliferation of these residential compounds, most of which are located in suburban areas, is one facet of recent urban change.

To provide some additional context about the residential compounds that are the subject of this study: residential compounds for white-collar professionals in Bahrain vary in size and amenities but generally have several characteristic features, including a number of uniform buildings enclosed by a wall, controlled access through a central security gate, and a common recreational area, usually located at the center of the compound. In larger compounds, this recreational area contains amenities such as swimming pools or tennis courts. Distinct morphological differences distinguish housing compounds from the surrounding Bahraini urban fabric: Figure 1 shows a representative housing compound and contrasts it with a representative example of a typical Bahraini residential neighborhood; both images are at the same scale.

The term "compound" in multivalent in Bahrain, as there are other compounds in Bahrain besides this study's subjects: Bahraini nationals may construct *family compounds* to house multiple members of an extended family, and some companies construct *company compounds* to combine administrative and logistical operations or to house blue collar workers; all of these may be referred to as *compounds* even though their functions and forms vary. However, these "other" compounds have different morphologies and are typically smaller in scale than the compounds that are the subject of this study.

Data Source

This study's data source, Wikimapia, is a mapping service in which users delineate (using polygons) and tag features at a variety of scales on a map interface – it is a spatially-explicit folksonomy. Annotations, in multiple languages, can be added in the form of text, photographs, video and external links. By June 2019, almost 30 million places had been added to Wikimapia and the site had over 2.5 million users, although a relatively smaller subset of these are regular contributors. Wikimapia has been mentioned as a relevant VGI source (Goodchild and Li, 2012; Barron, Neis, & Zipf, 2014), but studies of OSM dominate the VGI literature (see, for example, Haklay, 2010; Mooney & Corcoran, 2012; Canavosio-Zuzelski, Agouris, & Doucette, 2013; Barron, Neis, & Zipf, 2014; Ma, Sandberg, & Jiang, 2015; Zhang et al., 2015; Quinn & Yapa, 2016) and relatively little research has examined Wikimapia (see Bittner (2017) and Ballatore and Arsanjani (2018) for notable exceptions). However,

Figure 1. Representative housing compound for white-collar professionals (above); representative residential area (below). Source: Google Earth.

Wikimapia is a more appropriate data source for this project's purposes because it identifies many more compounds in Bahrain than OSM[2]; this confirms Ballatore and Arsanjani's (2018) assessment of Wikimapia as being relatively more popular in Northern Africa and the Middle East. Several issues should be noted when using Wikimapia as a data source. Contributors are not identifiable, which raises questions about their qualifications or motivations that are difficult to answer, and the service is relatively unsophisticated compared to OSM. Further, although Wikimapia is crowdsourced and CC-licensed, it is a private enterprise that generates income through ads. However, these issues do not preclude the use of Wikimapia, which is the most appropriate VGI source for the purposes of research on gated communities in Bahrain.

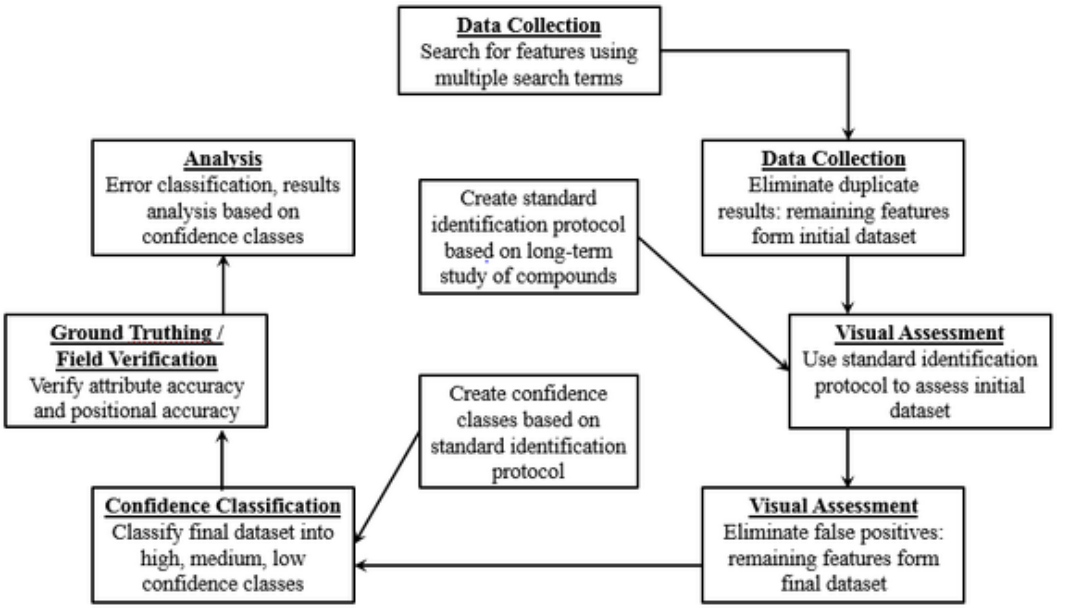
Bahrain's extensive land survey and registration apparatus creates updated, high quality cartographic products and is well integrated into local government operations. While municipal records and/or planning documents and permits doubtless exist, they are unavailable to the general public and academic researchers. Publicly available planning documents are of limited value for this study's purposes, as they do not label the features they indicate or provide metadata; other cartographic products are unavailable at the appropriate scale. VGI, thus, adds value to a study of gated communities in Bahrain as it provides geospatial data (that would be otherwise completely unavailable) to answer

important research questions. The obstacles related to lack of public access to geospatial data are not exclusive to Bahrain; these obstacles are also present in other global contexts.

PROCEDURE AND RESULTS

This methodology's *purpose* was to evaluate the data quality of Wikimapia in identifying the locations and names of gated communities in Bahrain. To achieve this, housing compounds tagged by contributors on the Wikimapia platform[3] were assessed, classified, and subjected to a field-based ground-truthing. Figure 2 provides an overview of the research procedure.

Figure 2. Research procedure workflow



- **Data Collection:** The names of many housing compounds include the "garden(s)" descriptor (e.g. "Altair Gardens", "Miami Gardens", "Inaara Garden"), even though these compounds are not actually gardens. Searches were done on Wikimapia, in English and Arabic, for all features in Bahrain that had been tagged by contributors with the "compound", "garden" and "gardens" tags. An example of such a tagged feature is provided in Figure 3. These searches identified 282 features; removing duplicate results eliminated 30 features. The *"initial dataset"* used in this research was thus comprised of 252 features tagged by Wikimapia contributors;
- **Visual Assessment:** Prior to field verification, the tagged features were visually assessed, using Wikimapia's integrated Google Maps basemap imagery, employing the following procedure: a standard identification protocol was created, drawing on knowledge of the local context, the various types of Bahraini compounds, and the characteristics of the compounds that are the subject of this study. This standard identification protocol used 6 characteristic attributes or structural features (e.g. multiple villas; identical villas; individual (detached) villas; centrally-located public space; recreational amenities, such as swimming pools or tennis courts; an exterior wall). Each tagged feature was visually examined to establish whether it appeared to be a residential compound; this was done by comparing the feature to the six-item standard identification protocol

Figure 3. Screenshot from Wikimapia illustrating how features – in this case, residential compounds – have been "tagged" by users. Source: Wikimapia.

and noting the presence or absence of characteristic structural features. The design of the standard identification protocol incorporated a qualitative dimension to the methodology, as did the visual assessment of each feature in the initial dataset.

After visually assessing the initial dataset's 252 results using the standard identification protocol and the characteristic structural features mentioned above, false positives were excluded because they were clearly not the housing compounds that were the subject of the study. False positives were present in the dataset due to the multivalent nature of the search query. For example, a vegetated garden would be labeled in Wikimapia as "garden" and would be returned in the search results. After comparison to the standard identification protocol, it would be excluded from the analysis, while a housing compound with "garden" as part of its name would be retained for further analysis (Figure 4).

If doubt existed about a feature, it was retained in the dataset. After a visual comparison of each of the 252 initial results against the standard identification protocol, 95 features were eliminated from the dataset prior to the classification and ground-truthing steps described below. This resulted in a *"final dataset"* of 157 features. The precision of the initial query (the proportion of retrieved results that were relevant) was just over 66 percent.

- **Confidence Classification:** The completion of the visual assessment produced a final dataset of 157 unique features. The visual analysis of the presence or absence of six specific, characteristic structural features of residential compounds (as outlined above), allowed these 157 features to be categorized into one of three confidence classes: low (1-2 of the 6 characteristic attributes visible); medium (3-4 of the characteristic attributes visible); high (5-6 of the characteristic attributes visible). For example, a feature would be placed in the low confidence category if feature had no common space or recreational facilities and the individual homes were clearly not uniform. One reason to use the confidence classification system is the multivalence of the "compound" term; while residential compounds for white-collar professionals are one common type of compound, other features could be tagged by users as "compounds"[4]. The use of a confidence classification based on visual analysis adds another qualitative dimension to this methodology;
- **Ground Truthing / Field Verification:** All 157 features in the final dataset were ground truthed to determine whether Wikimapia contributors had simultaneously: a) correctly identified the structure as a residential compound (one form of attribute accuracy), b) correctly provided its location (positional accuracy), and c) provided the compound's correct name (another form of attribute accuracy). Successful verification required

Figure 4. Two different types of features, both tagged with the "garden" tag on Wikimapia. The feature in the upper screenshot is clearly an agricultural area, while a series of identical homes and a centrally-located recreational area indicate that the feature in the lower screenshot is a residential compound. Source: Wikimapia.

accuracy on positional and both attribute dimensions. Verification was done manually due to the lack of publicly available maps or datasets. To provide the most complete data quality assessment, each feature in the final dataset was verified as opposed to verifying a sample. Some tagged features could not be verified for a variety of reasons. For example, field verification would fail if a compound was present at the specified location, but the compound name on Wikimapia was incorrect (lack of attribute accuracy). Another example of the failure of field verification is if a tagged structure lacked any exterior signage or similar indicators of being a compound. Table 1 indicates the number and percentage (user's accuracy) of identified features that were verified in the field, demonstrating both positional and attribute accuracy.

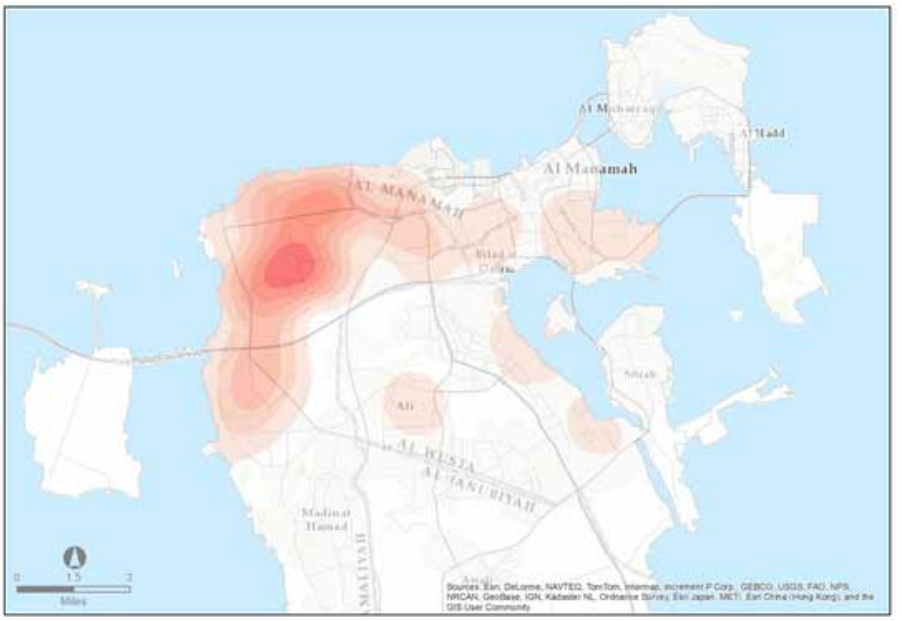
User's accuracy reached just over 90 percent of the features in the high confidence class and 85 percent of the features in the medium confidence class. Only 38.5 percent of the features in the low confidence class could be verified. Overall, visual assessment with a standard identification protocol, followed by field surveys and ground truthing, found that Wikimapia contributors correctly identified the locations and names of 85.4 percent of the compounds they tagged.

Table 1. Number and percentage of features identified and verified as being accurately labeled and located from user-generated content

	Confidence Classification			
	High	**Medium**	**Low**	**All Classes**
Features identified	117	27	13	157
Features verified	106	23	5	134
Features that could not be verified	11	4	8	23
Percent verified (user's accuracy)	90.6%	85.2%	38.5%	85.4%

- **Mapping:** The 134 unique results were digitized in ArcGIS to produce a detailed map of compound locations. A density map of compounds derived from the detailed map is shown in Figure 5. The data needed to produce such a map was not publicly available prior to this research; the map represents a valuable contribution to wider research on gated communities in Bahrain, as it sheds light on the spatiality and intensity of the forces shaping contemporary Bahraini urbanization processes. For example, Figure 5 indicates the suburbanization of gated communities, as well as patterns of gated community concentration in specific neighborhoods in northwest Bahrain.

Figure 5. Compound density map derived from field-truthed VGI



Error Classification

Table 1 indicates that 23 of the 157 tagged features could not be verified as being residential compounds, reflecting inaccuracy in the location and/or the labelling of the tagged feature. Further analysis examined these errors of commission. Field verification revealed that seven of these 23 features were indeed correctly located and labelled as compounds but were not the type of residential

compounds for white-collar professionals that is the subject of this study[5]. Thus, only 16 features were unverifiable because they did not exhibit simultaneous positional and attribute accuracy. Of these 16 "unverifiable" features, eight exhibited *attribute inaccuracy* (50 percent of the 16 unverifiable features, or 5 percent of the final dataset of 157 tagged compounds); these eight features were correctly identified as residential compounds but *incorrectly labeled*. These errors could be due to an incorrect label, or the compound name might have changed between the time of label creation and field verification. Five of the 16 features were correctly identified as residential compounds but lacked a visible indicator of the name. Given that 13 of the 16 "unverifiable" features were correctly identified by Wikimapia contributors as being residential compounds, 154 of the 157 features (98 percent) tagged as compounds were verified as being compounds (albeit of various types). There was only one confirmed case of positional inaccuracy, which is defined as a situation in which the spatial marker on Wikimapia was incorrectly positioned; it cannot be ruled out that the two remaining unverifiable cases were also due to positional inaccuracy. Thus, between one and three of the unverifiable cases exhibited *positional inaccuracy* (between 6 and 19 percent of the 16 unverifiable features, or between 0.6-2 percent of the final dataset of 157 tagged compounds).

DISCUSSION AND IMPLICATIONS

Discussion and Implications: Gated Communities

Neoliberal urbanism examines the production and exploitation of sociospatial difference, new forms of social polarization, and uneven development (Peck et al., 2009). As they reflect market-oriented real estate development, replication of global design trends, and the securitization and privatization of space in the city, gated communities for white-collar professionals are one facet of neoliberal urbanism in the Gulf city. Examining how different forms of housing reflect and relate to processes of fragmentation and social polarization broadens our understanding of contemporary urbanization processes in the Global South. The Bahraini case study illuminates how residential gating and segregation have spread down the global urban hierarchy. Within the Gulf, larger cities such as Dubai understandably garner disproportionate scholarly and public attention (Elsheshtaway, 2008; Smith, 2010; Ewers, 2017); this project follows Robinson (2006) in arguing for a broader account that takes into consideration the diversity and distinctiveness of ordinary, smaller cities that are relatively overlooked.

To conduct a study of gated communities, one must first understand their scope and prevalence. Given that authoritative data on this topic is publicly unavailable in Bahrain, alternative data sources can potentially make a positive contribution. Gated communities are a complex, contested phenomenon that can benefit from mixed methods approaches. This research is part of a larger effort analyzing the experiences of compound residents. The results of the case study presented here contribute to understanding the prevalence, spatial distribution, and locations of gated communities (Figure 5), which are critical building blocks when studying the scope of residential gating in Bahrain and contextualizing resident experiences. Indeed, because compounds are often found in clusters, Wikimapia-derived identification of high density areas helped to locate other features of interest not tagged in Wikimapia. As such, this case study aligns with other research that has documented the contribution of user-generated geospatial content to studies of urban structure (Chen et al., 2019).

Some research on gated communities has analyzed their locational patterns (De Duren, 2006; Richter & Goetz, 2007; de Araujo & de Queiroz, 2018), while other research on gated communities seeks to establish typologies of gated developments (Hirt & Petrovich, 2011; Blander, Moser, & Avni, 2018; La Grange, 2018); this case study demonstrates how the kinds of data generated by Wikimapia can advance these types of studies. By assessing its accuracy, this study has validated Wikimapia's potential as a data source for research on urbanization, paralleling research on other forms of VGI (Arribas-Bel, 2014; Shelton, Poorthuis, & Zook, 2015).

The added value of using VGI to study gated communities in this case study is that VGI provides the only accessible source of data in an otherwise data-poor context. Given that the type of data presented here is publicly unavailable, Wikimapia's ability to identify specific elements of the urban structure made it a valuable data source. This has broad implications, beyond the specifics of this case study, for researchers working in data-poor contexts, whether they may be conducting pilot studies, making decisions on research methods, or conducting research.

The locational data generated by this study can be a basis for research in several other directions. These include spatially explicit sampling of gated communities, GIS analysis of gated community size and spatial distribution, and cross-referencing with other data sources. Furthermore, in conjunction with remote-sensing, this locational data can help in understanding the temporal growth of residential gating. Small-scale studies of particular components of the housing market, such as gated communities, contribute to understandings of large-scale trends of socioeconomic polarization, planning, and residential dynamics in contemporary Gulf cities. As such, these studies may benefit urban scholars, planners, and residents.

Discussion and Implications: Wikimapia Data Quality

Based on long-term study of gated communities in the Gulf, knowledge of the local context was used to create the 6-item standard identification protocol. The qualitative methods used here included visual assessment of the initial dataset, followed by the confidence classification according to the standard identification protocol. The results presented above demonstrate Wikimapia's utility in identifying elements of the urban structure; complementing Wikimapia data with qualitative methods and knowledge of the local context can increase accuracy. The qualitative methods employed in this study are robust, can be reproduced, and may be assessed in other contexts.

As shown in Table 1, 90.6 percent, 85.2 percent, and 38.5 percent of the features in the high-, medium-, and low-confidence classes, respectively, were accurately located and labeled on Wikimapia. Field verification of Wikimapia's data quality found high overall *attribute accuracy* (95 percent of all tagged features), and very high *positional accuracy* (between 1 and 3 cases were inaccurate; 98-99.4 percent of all tagged features were positionally accurate). Depending on the specific research application, different types of inaccuracy may be more or less acceptable. For example, when researching the spatial extent of compounds, attribute accuracy may be less important than positional accuracy. Further, different VGI sources would be expected to have different types of errors, based on the type of user input (i.e. whether data is provided actively or collected in a more passive fashion), the locational context, and so forth.

By evaluating Wikimapia's data quality, this case study has demonstrated Wikimapia's utility as data source for urban research in a data-poor context; this parallels studies of the data quality of other forms of VGI. For example, an assessment of the accuracy of OSM building footprint data in Munich (Fan et al., 2014) reported high levels of completeness and some error in positional accuracy; it is worth noting that Munich is one of the most developed cities in OSM. The case study presented in this research, in a Global South context, reveals similar results. Also, this case study indicates that the majority of errors in the VGI dataset were related to tagging and annotation, which corroborates research in other contexts, such as Mooney and Corcoran's evaluation of 25,000 heavily edited OSM items in Ireland, Germany, Austria, and the UK (2012). The implication is that, within broad parameters, data quality aspects of VGI may exhibit some commonality across a variety of contexts, even when different approaches (e.g. automated, manual) are employed.

LIMITATIONS

This project uses a single data source. While Wikimapia is a rich data source that was the most appropriate for the subject of this study, adding information from other VGI sources could provide useful information and potentially allow the cross-referencing and verification of urban structural

features. For example, photo-sharing sites such as Panaramio, Flickr, and Twitter are potential sources of georeferenced photographs.

A broad limitation inherent to Wikimapia relates to the fact that contributors tend to be a relatively narrow and homogenous group (Haklay, 2012), which implies an inherent skew to the data that cannot be ignored. This study focuses on *features* in Wikimapia; a study of the contributors of these features is beyond the scope of this project. The effects of contributors on this study cannot be directly ascertained. It is possible that the bias of contributors might cause oversampling of some types of compounds and undersampling of others (e.g. compounds that are geared towards upper-class residents might be more likely to be tagged by contributors). When considering the potential homogeneity of Wikimapia contributors, it is worth noting that a number of tags and descriptions examined in this study were made in Arabic; the contributors to VGI in this non-Western context were not linguistically homogenous.

This project focuses on Wikimapia's *correctness*, its simultaneous positional and attribute accuracy, rather than its *completeness*. This is not to take a position on arguments about abandoning the concept of completeness. Rather, because the scope of this particular project requires focus on a particular element of VGI data quality, this project focuses on errors of commission rather than omission; the latter is a topic for future research.

Finally, this study assesses a particular specification and setting, and a manual method (ground-truthing). As mentioned earlier, factors such as access, time, and resources make the ground-truthing approach relatively less common. The success of the case study presented here, in conjunction with Bahrain's small size and relatively average VGI "density", implies that the approach presented here can be extended to pilot studies and small- and medium-scale projects in other contexts. This paper does not mean to suggest that a study of large numbers of features in a sprawling urban area would be as well-served by this approach.

CONCLUSION

This paper has demonstrated Wikimapia's utility in a study of urban settlements and structure. User-generated geospatial content provided the information needed to identify elements of urban structure (in this case, particular forms of housing) with a sufficiently high level of accuracy, given the nature of the specific study. To assess the spatial extent of gated compounds, the alternative (in the absence of Wikimapia or other VGI sources) would have been a more time- and cost-intensive field survey process.

Combining local and/or expert knowledge (in this case, through the development of the standard identification protocol and the confidence classification system) can increase the utility of user-generated content for studies of urban issues. The integration of qualitative methods and/or local knowledge with VGI can be reproduced in other urban research settings as the research questions warrant. Urban researchers who wish to use VGI should note that data quality is subjective (Cooper et al., 2011) and that quality depends on, among other factors, the applications in which such data will be used.

This study illuminates differences often subsumed within the broader category of VGI. Haklay (2010, 700) identifies a digital divide whereby 'nice places' that have middle classes with enough educational attainment, equipment, and leisure time will be covered by VGI, while those with scarce or deprived populations are potentially marginalized by VGI. Based on the results of this case study from the Global South, this paper goes a step further, arguing that not all forms of VGI are equal: uploading GPS tracks to OpenStreetMap is one type of investment, the reconstruction of 3D buildings in OpenStreetMap, is another, and drawing and labeling polygons in Wikimapia is yet another. Therefore, researchers considering the use of VGI should note that contexts that might initially seem to be on the less advantaged side of the digital divide may, in fact, be better represented

than might initially be expected. As larger cities attract disproportionate research interest, this case study contributes to efforts to tackle research questions in the (numerous) smaller cities of the world.

To summarize:

- The case study presented here illustrates Wikimapia's utility and accuracy in providing data in support of studies of urban settlements in general and analyses of urban structure in particular. Specifically, the practical question addressed here was whether or not the locations and patterns of gated communities in a data-poor context could be accurately determined using VGI;
- Wikimapia's data quality was measured in terms of simultaneous positional and attribute accuracy. After a visual analysis and a confidence classification, a Wikimapia-derived dataset was found to have sufficiently high data quality to be able to successfully locate and identify features in the urban environment;
- The level of data quality identified in this project demonstrates how Wikimapia may be successfully leveraged as a data source for research on urbanization, based on the purposes of the specific project;
- When features could not be verified due to a lack of either attribute or positional accuracy, the most common type of errors was found in attribute accuracy (50% of the 16 "unverifiable" cases were accurately located but inaccurately labeled). Errors in positional accuracy were less common (6-19% of the errors). These errors represent 5% and 2%-0.6% of the final dataset, respectively;
- This case study is purposefully focused, based on a study of gated communities and their residents, but the results are significant for the larger field of urban studies and can have broad implications for other projects and contexts;
- From a data quality standpoint, VGI may be a promising data source in data-poor and/or non-Western contexts when studying cities where authoritative spatial data is not readily available.

In the case study presented here, VGI provided valuable insights on the prevalence of gated communities, which are significant but understudied parts of the Gulf city's urban structure. This topic may be of interest to researchers examining broader processes of socio-economic polarization. This project assessed VGI's utility in a study of gated communities in a less-researched context, but further assessments of VGI's utility could be tailored to any number of urban studies research projects and contexts. For urban scholars and others not specializing in VGI, this paper is intended to move beyond a strictly technical assessment of Wikimapia data quality to provide a step-by-step explanation of replicable and robust research procedures that may be significant to other projects involving urban structure and settlements.

To the author's knowledge, this is the first assessment of the accuracy of volunteered map annotations in the (relatively data-poor) Middle Eastern context. This paper makes several contributions beyond the specifics of the case study. First, Wikimapia has been largely neglected in studies of the quality of VGI, as OSM has received far more academic attention (see, for example, Haklay, 2010; Mooney & Corcoran, 2012; Canavosio-Zuzelski, Agouris, & Doucette, 2013; Barron, Neis, & Zipf, 2014; Ma, Sandberg, & Jiang, 2015; Zhang et al., 2015; Quinn & Yapa, 2016). This project does not argue that Wikimapia is a representative example of the more general term of VGI. Instead, this project seeks to narrow existing gaps in research on the large, heterogeneous body of work that is VGI, through an examination of a specific and understudied form of VGI. Second, given the preponderance of research on VGI in North American and European contexts, and in particular the smaller subset of studies examining how urban research can utilize VGI (see, for example, Shelton, Poorthuis, & Zook, 2015; Vaz & Arsanjani, 2015; Boy & Uitermark, 2016; Hachmann, Arsanjani, & Vaz, 2018), this paper presents empirical work from a smaller city in the Global South to demonstrate how urban research in understudied parts of the world can draw on volunteered geographic information. Third, studies of volunteered geographic information quality have generally not used ground-truthing (Senaratne

et al., 2017); as such, this project examines a relatively less common data quality assessment method that may be of use in particular settings and contexts.

This research assessed Wikimapia's accuracy in identifying specific elements of urban structure. Because errors of omission are beyond the scope of this research, this project is primarily concerned with errors of commission. Further research can: a) assess errors of commission and omission; b) examine VGI's accuracy using several measures (both ground-truthed and reference) to determine whether there are substantive differences.

Gated communities have spread around the world and down the urban hierarchy. Understanding the prevalence and spatial distribution of these forms of housing is a key step towards understanding their relationship to the larger city, as well as their causes and impacts. As demonstrated in this paper, Wikimapia can be a valuable data source for a study of urban structure. More than a decade ago, Goodchild's seminal paper argued that VGI's most important value may be "what it can tell about local activities in various geographic locations that go unnoticed by the world's media, and about life at a local level" (2007, p. 220). The empirical case study presented in this paper supports this assertion, reflecting the potential value of Wikimapia in particular, and VGI more broadly, for research - particularly for urban studies - in ordinary spaces and places where spatial data is not freely available.

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ENDNOTES

1. To reflect common local usage, these gated communities are referred to as "residential compounds" or "compounds" in this paper.
2. OSM has its own strengths; for example, in Bahrain, the density of OSM's road network is higher than that of Wikimapia's; OSM would be a more appropriate data source for a road-focused study.
3. http://wikimapia.org
4. Any subunits tagged as compounds were not included in the analysis, for example, if a Wikimapia contributor had tagged a particular house on the property, or the compound's gate, that tag would not be included in the analysis.
5. These seven compounds included four family compounds and three company compounds.

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