GIS for planning a sustainable and inclusive community: multi-criteria suitability analysis for siting low-income housing in a sustainable community and suitable neighborhood in Buffalo Metropolitan Area, New York

I Saleh¹ and N D A Setyowati²

¹ Department of Architecture Education, Faculty of Technology and Vocational Education, Universitas Pendidikan Indonesia (UPI), Jl. Dr. Setiabudi No 229, Isola, Sukasari, Bandung, Jawa Barat, Indonesia
² The Ministry of Agrarian Affairs and Spatial Planning/National Land Agency (ATR/BPN), Indonesia

Corresponding author’s email: ilhamdaniah@upi.edu

Abstract. This study utilized Geographic Information System (GIS) as a tool for sustainable community planning which incorporates low-income communities into current sustainable neighborhoods. GIS suitability analysis aimed at finding suitable and sustainable neighborhoods for locating subsidized housing projects for low-income families through the Low-Income Housing Tax Credit (LIHTC) program in the Buffalo Metropolitan Area (BMA), New York. LIHTC projects allocate 30% of their rental units for low-income families. They must be located in sustainable neighborhoods to ensure economically and socially sustainable lives for low-income inhabitants. Data was collected from various New York State government agencies and used as input for several raster-based criteria maps using GIS network analysis, raster cost-distance analysis, Kernel density analysis, raster-based local statistics, and surface analysis. The criteria of sustainable neighborhoods using GIS multi-criteria analysis (MCA) were grouped into five factors, namely public amenities, economic viability, population growth, property conditions, and environmental factors. A final suitability map was created by multiplying the derived raster maps with their respective weight resulting from the Analytical Hierarchical Process (AHP). The study found several locations in suburban areas of the BMA that meet the criteria and can be used by the Buffalo Metropolitan Housing Authority (BMHA) to site the LIHTC housing.

1. Introduction
1.1. Background
Planning a sustainable community, particularly planning a sustainable and inclusive low-income community, is a daunting challenge. One of the challenges of locating housing for low-income households is to find an area that allows low-income inhabitants to have a sustained life. A sustained life refers to the ability to live in a sustainable neighborhood, or opportunistic neighborhood, that allows its residents to have job opportunities for their financial stability and allows them to benefit from the strong social capital of the community in that neighborhood. This is in line with the concept of sustainable communities that integrates environmental, economic, and social objectives [1].

Content from this work may be used under the terms of the Creative Commons Attribution 3.0 licence. Any further distribution of this work must maintain attribution to the author(s) and the title of the work, journal citation and DOI.
Published under licence by IOP Publishing Ltd
The United States Federal Government through the Housing and Urban Development Agency and local housing authorities has developed policies and efforts to provide affordable housing for low-income households [2]. One of the housing programs provided by the United States Federal Government that specifically address the provision of housing for low-income families is the Low-Income Housing Tax Credit (LIHTC) program. The backlog of housing units and the rising cost of housing issues for providing affordable housing for low-income families. LIHTC dedicates some portion of its rental unit development for low-income families. LIHTC projects are proposed by private developers to housing authorities in US cities. The approved projects will receive a subsidy from the federal government in the form of a tax credit for private developers credit for constructing the housing. LIHTC is considered as a project to provide affordable housing for low-income families because the developments must allocate 30% of the rental units for low-income families to be able to obtain the tax credit.

The location of LIHTC in a suitable and sustainable neighborhood is crucial for the sustainability of this housing program and for the sustained life of its future inhabitants. In the long run, the low-income families residing in the subsidized rental housing funded by LIHTC are expected to have a more sustainable living condition (economically and socially) after moving to an opportunistic neighborhood away from the poverty-ridden inner city. By living in a sustainable opportunistic neighborhood, they are expected to have access to better sources of livelihood, are exposed to more economic opportunities, have greater access to public amenities, can access greater social capital, and live in a good quality neighborhood.

There are challenges in the provision and selection of sites for subsidized housing for low-income families. Currently, in US cities, subsidized housing projects are located in deteriorating neighborhoods with high poverty, high crime rate, low school quality, and low accessibility to quality urban public services. The recent LIHTC projects are mostly located in distressed areas. Small portions of the LIHTC projects are in suburban areas, while most are in disadvantaged neighborhoods. Disadvantaged neighborhoods do not provide long-term conducive conditions and opportunities for low-income families. Previous studies on US cities have confirmed that previous government-subsidized housing schemes (public housing and housing vouchers) were mostly located in disadvantaged neighborhoods with concentrated poverty. A prominent study examined the current spatial distribution of subsidized housing programs (housing vouchers and LIHTC) in Erie County. It found that the recipients of subsidized housing in the Buffalo Metropolitan Area (BMA) are clustered in the disadvantaged neighborhoods in the city of Buffalo and in the inner suburban area of BMA[3]. These locations have limited capability for improving opportunities for low-income families because the location of subsidized housing is prevalent in disadvantaged neighborhoods[4]. Location wise, LIHTC projects are better off compared to their subsidized housing programs counterparts, such as public housing and housing vouchers [5].

The siting of affordable low-income housing in neighborhoods that provide opportunities for its residents is important. Local Housing Authorities plans and determines policies for low-income housing in the city and is funded by the Internal Revenue Service (IRS). Currently, the housing authority has limited ability to plan LIHTC locations that consider numerous influential factors. The provision of affordable housing for disadvantaged groups in opportunistic neighborhoods will assist them to escape the vicious cycle of poverty and escape distressed neighborhood. Suitable LIHTC sites would improve economic opportunities and chances for livelihoods of low-income housing recipients.

Buffalo Metropolitan Area (BMA) was selected as a case study area to depict the process of finding suitable locations for LIHTC projects. Finding suitable locations in opportunistic neighborhoods within a sustainable community is a challenge. This is exacerbated by the conditions of metropolitan that face the problem of shrinking, and declining population as well as resident segregation. This is especially challenging for the case of Buffalo.

Various scholars have attempted to plan subsidized housing locations. One study has dealt with this issue and identified suitable low-income housing sites on the eastern side of the Bangkok Metro area. It was conducted via the use of GIS-based analysis to locate the public [6]. Housing sites based on
various criteria, such as location, infrastructure, land cover, and natural environmental factors. Another study incorporated the variables of accessibility to services [7]. Yin and Muller [8] incorporated two-dimensional and three-dimensional criteria for siting the residential project in the exurban area of Colorado. Numerous scholars have developed a planning support system model to find suitable and desirable areas in which subsidized housing can be located to serve low-income families [5,9,10]. They used mathematical models to select locations and configurations for affordable housing. Their studies addressed various programmatic and physical attributes associated with affordable housing. With only a handful of literature pertinent to siting low-income housing, more studies are needed to properly analyze opportunistic neighborhoods, qualified neighborhoods, or neighborhoods with sustainable communities to site the LIHTC project.

Multi-criteria analysis (MCA) is a methodology that compares different options and their merits by using a range of quantitative and qualitative criteria [11]. MCA can be performed spatially by using Geographical Information Systems (GIS) [12]. Various stepwise procedures in GIS-based multi-criteria analysis (GIS-MCA) can analyze single or multiple objectives. Thus, GIS-MCA has been applied in many fields, e.g., environment, geography, soil science, land-use planning, and community planning. GIS-MCA has also been applied in suitability analysis, for example, Malczewski[13] studied land-use suitability analysis.

1.2. The Relevance of this Study
There is a sizeable gap in the literature on siting low-income housing located in a declining and segregated metropolitan area. Therefore, more study is needed to properly analyze locations of opportunistic neighborhoods (qualified neighborhood) to site the LIHTC in a segregated metropolitan area. There is a need for a planning methodology that could help determine the qualified locations in a metropolitan area for use by private developers to develop rental housing projects for low-income families. This study attempts to solve the problem of selecting suitable locations for LIHTC. The significance of this study is that it can help ensure that LIHTC rental housing units are located in neighborhoods that can help improve the economic opportunities, access to public amenities, and social capital of the low-income family residing in the rental housing.

This study utilizes GIS-based multi-criteria suitability analysis for subsidized housing in the Buffalo Metropolitan Area, Erie County. It does so by considering the current spatial distribution of subsidized housing in the BMA, the current planning practices in BMHA, and the potential of multi-criteria decision-making analysis to help plan for the siting of subsidized housing. The above-mentioned literature offers insight into this study into the kind of variables that should be incorporated in the suitability analysis. This study also utilized an Analytical Hierarchical Process to objectively assign weights to the criteria.

1.3. Objectives
The objective of this study is to find alternative suitable locations for inclusive low-income housing projects which will be funded by the Low-Income Housing Tax Credit program. This is to ensure economically and socially sustainable livelihoods of low-income households in the Buffalo Metropolitan Area. The GIS-based multi-criteria suitability analysis was utilized to achieve this objective.

1.4. Structure of the Paper
This paper is organized into five sections. The first section is the introduction, which sets the study objectives and the contribution of the research. The second section focuses on reviewing the literature related to this topic. The third part of this paper discusses the methodology. Fourth, results and discussion. This paper is closed with a conclusion and advice for further studies.
2. Methodology
This section describes the data collection and methods of data analysis. These consist of secondary data collection, GIS data processing, and GIS spatial analysis comprising GIS-based multi-criteria suitability analysis.

2.1. Method of Data Collection
Data was collected from various secondary data sources. The New York State (NYS) tax parcel map was used to find information about the location of neighborhood commercial areas, as well as the industrial sites and residential land uses. Data on neighborhood parks were also retrieved from the NYS tax parcel map. Spatial data on the location of public schools was catered by the NYS Clearing House. Moreover, data about the quality of schools (elementary schools) was collected from the New York State Department of Education (NYSED) as well as data on the location of public transits (bus stops and light rail stations). Population data was gathered from the census database [14]. The data collected were data on the total population, race composition, poverty, housing rent, and median household income. Furthermore, data of land/property value was retrieved from the city tax assessment whereas data of job numbers in blocks were downloaded from the LODES census data set and aggregated in the block group level. The Digital Elevation Model of Erie County was retrieved from the United States Geological Survey (USGS DEM) and was used to create a raster map mosaic of Erie’s elevation and slope. Finally, the data of land use designated for residential areas in Erie county were also collected.

2.2. Data Analysis Method
Several GIS spatial data analysis methods were conducted to create input maps, i.e., network analysis and spatial analysis (cost-weighted distance, cell statistics, vector analysis, surface analysis, raster conversion, and raster classification). Furthermore, GIS multi-criteria analysis was conducted in the weighting process. The data analysis methods and procedures are depicted in Figure 1.

![Figure 1. Steps to conduct GIS-based multi-criteria suitability analysis for siting subsidized housing in a sustainable community](image-url)
2.2.1. The GIS Spatial Analysis Process

Network analysis was conducted to calculate the distance to neighborhood commercial centers and the travel time to a state park. In addition, the cost-distance analysis was conducted to calculate the distance to a good-standing public school (elementary schools). Moreover, euclidean distance to industrial sites was calculated to illustrate areas with clean air, that are farther from the industrial areas. Ease of access to public transportation was calculated using the Global Statistics Kernel density by calculating the density of bus stops. The higher density means that those areas are accessible by public transportation. Zonal statistics were utilized to calculate the number of neighborhood parks within a block group. This indicates the density of neighborhood parks in the area, with block groups as the zone boundary for analysis. Local statistics were utilized in calculating the population change in the study area. Visualization of population, economic, and land/property variables in polygon files were done using the vector analysis method. Surface analysis was performed to create a slope map. The slope was developed from the Digital Elevation Model (DEM) of Erie County. Maps from the previous data preparation process, which were still in vector data, were converted to raster. Furthermore, all raster maps were be individually reclassified into five classes (ranging from the value of 1-least suitable to 5-most suitable). Reclassified raster maps were grouped based on their clusters, such as public amenities, economics, population, property, and environmental factors (refer to Figure 1). The derived maps and reclassified maps were visualized in ArcGIS (Figure 2 to Figure 5).

2.2.2. The GIS Multi-criteria Analysis Process (GIS MCA)

The relative importance of the criterion is expressed using weight. Assigning weights for the variables can be done based on literature or expert judgment. Weight assignments for each criterion can be assigned subjectively or objectively using expert knowledge in a pairwise comparison method [15]. In the case of siting subsidized housing, current literature only showed the variables incorporated in the process of selecting locations for subsidized housing. No literature had been found about the quantitative weights of variables. Therefore, this study proposes the Analytical Hierarchical Process (AHP) with pairwise comparison to set the weights for the factors and variables. Within each cluster, each variable was assigned weights. In the end, each cluster was assigned weights using another round of AHP analysis.

3. Results

Table 1 describes and justifies the criteria for the study objective. The criteria are listed and arranged in the clusters or groups of criteria. There are five clusters of criteria to be considered in this multi-criteria suitability analysis. In total, there are fourteen criteria (see the attachment). The literature from previous studies is cited to justify the selection of variables. Intermediate maps for each group of criteria were produced as inputs for GIS multi-criteria analysis. Each map was given a weight for calculating the final map using GIS-based multi-criteria analysis. The weights for each group of criteria resulting from the Analytical Hierarchical Program (AHP) are public amenity factors (0.29), economic factors (0.20), population factors (0.12), land and property factors (0.31), and physical environmental factors (0.07). Intermediate raster maps are calculated using map algebra for each cluster of variables. Those intermediate maps are depicted in Figure 2 to Figure 6 whereas the final suitability map is depicted in Figure 7.
Table 1. Criterion and Group of Criteria

| Number | Criterion | Description | Literature |
|--------|-----------|-------------|------------|
| 1      | Proximity to neighborhood commercial centers | Preferably located near neighborhood commercial area | Zhu, Liu, and Yeow (2006) [7] |
| 2      | Proximity to good quality schools | Preferably located near good quality school | Deng (2007) [16] |
| 3      | Density of public transits | Preferably located at areas with high bus stops density | |
| 4      | Density of neighborhood parks | Preferably located in neighborhoods with a high number and density of neighborhood parks and playgrounds in the block group | Talen & Anselin (1998) [17] |
| 5      | Density of job opportunities | Located in areas with many job opportunity | |
| 6      | Medium household income neighborhood | Preferably located in medium to high-income neighborhoods (mixed) | Michael P. Johnson, (2007) [5] |
| 7      | Poverty rate | Preferably located in low-poverty neighborhoods (10-20% poverty) | |
| 8      | Population change | Preferably located in neighborhoods with dynamic population growth | Deng (2011) [18] |
| 9      | Neighborhood racial composition | Preferably located in neighborhoods with inclusionary/mixed racial composition | Deng (2011) [18] |
| 10     | Housing rent | Preferably located in neighborhoods with rent above the county average | |
| 11     | Land value | Preferably located in areas with reasonable land value/price | |
| 12     | Gentle slope | Preferably located at areas with a gentle slope (0 - 15 degree) | |
| 13     | Clean air (far from industrial/manufacturing sites) | Far from industrial/manufacturing sites/brownfields | |
| 14     | Distance to state/county parks | Preferably located within proximity of state/county parks | |
|        | Land Use Criteria Restriction: Residential Land Use | | |
Figure 2. Group of Criteria 1: Availability and access to public amenity

Figure 3. Group of Criteria 2: Economic factors

Figure 4. Group of Criteria 3: Population factors

Figure 5. Group of Criteria 4: Land and property factors
Figure 6. Group of Criteria 5: Environmental factors

Figure 7. Final suitability map

4. Findings
This study produced a final map that presents the designated location suitability scores for subsidized housing. The highest suitability scores (4-5) indicate the most suitable location for subsidized housing in the LIHTC project. The locations in Figure 7 with the orange to red color indicate locations with lower suitability scores. Meanwhile, the greenish color indicates locations with the highest suitability. The highly suitable locations are in the suburban areas of the Buffalo Metropolitan Area. Ultimately, land use restrictions must be considered. Therefore, the final suitability map needs to be overlaid with residential land use.

As depicted in Figure 7, four clusters of neighborhoods have high suitability scores. These high suitability scores mean that the neighborhoods have the potential to sustain the economic livelihoods and enhance the social capital of future low-income households. Those neighborhoods are two suburban neighborhoods in the North East (Williamsville and Heim), one suburb located in the South East (Orchard Park), and one outer suburban Frontier neighborhood in the South West of the BMA. Based on the GIS-based MCA of this study, those neighborhoods can house LIHTC projects. These neighborhoods can inclusively incorporate low-income neighborhoods within a current sustainable and thriving community.

5. Discussion, Limitations, and Recommendations
The findings of this paper suggest that the location of subsidized housing should gravitate toward sustainable suburban neighborhoods in the BMA. The suitability analysis identified four clusters of block groups/neighborhoods. By considering these multiple criteria, the Qualified Census Tracts, which are potential for a sustained LIHTC project, are identified. They are mostly located in the suburbs of metropolitan Buffalo, Erie County. The proposed sites provide better accessibility to public amenities, higher quality of schools, more economic opportunities, less poverty, and neighborhoods with better environmental quality. Those suburban areas could provide low-income households with economic and social sustainability. Those factors ensure economic and social sustainability for low-income families to escape from the vicious cycle of poverty in the urban neighborhoods where they are originally located.
This study has demonstrated the utilization of GIS-based suitability analysis to find suitable locations for subsidized housing in a sustainable community in the Buffalo Metropolitan Area, New York. GIS analysis utilized many tools. The results can inform decision-makers in housing planning (Housing Authority) about suitable neighborhoods for developing LIHTC subsidized housing. This information can be used to approve or disapprove LIHTC location proposals by private developers.

There are three notable limitations to this study. First, GIS suitability analysis is subjective and biased. The subjectivity lies in the selection of criteria and weight assignment for the criteria. However, to minimize the subjectivity in assigning variable of importance, this study weights the criteria based on current literature and the Analytical Hierarchy Process. Hence, AHP reduces the subjectivity in determining the weight. Secondly, to eradicate this limitation, expert judgments can be used to select and weight the criteria. The more stakeholders involved in the consensus to determine the variable selection and weighting, the better the result (i.e. Focus Group Discussion or questionnaire can cater more insights for weighting the criteria). The incorporation of more variables will make the study more comprehensive. Nevertheless, there is a trade-off between incorporating more variables and the complexity of the suitability analysis. Third, this analysis can help narrow down potential locations, but ground checking the identified locations are needed to obtain additional information.

For future studies, there are two proposed research avenues. First, the determination of the weight in SMCA would be better if it is based on consensus from expert judgment or questionnaires to broader stakeholders. The second proposed research avenue is the incorporation of other variables such as existing subsidized housing in suburban neighborhoods. Prior research indicates that subsidized housing tends to cluster together; therefore, the inclusion of this variable of existing subsidized housing in the neighborhood will likely improve the result of GIS suitability analysis in the future.

Acknowledgments
The authors would like to acknowledge the support and supervision from Dr. Li Yin in the analysis process and in writing the preliminary report of this minor research project at University at Buffalo, The State University of New York.

References
[1] Roseland M 2000 Sustainable community development: Integrating environmental, economic, and social objectives Progress in Planning 54 73–132 https://doi.org/10.1016/S0305-9066(00)00003-9
[2] Schwartz A F 2015 Housing Policy in the United States (New York: Routledge) DOI: 10.4324/9780203955987
[3] Patterson K 2011 Stuck in Buffalo, But Why?: Residential Spatial Patterns of Housing Choice Voucher Holders in a Rustbelt City Fair and Affordable Housing in the U.S. ed. Silverman R M and Patterson K 181-241 (Leiden: Brill)
[4] Talen E and Koschinsky J 2014 The Neighborhood Quality of Subsidized Housing Journal of American Planning Association 80 67-82 DOI: 10.1080/01944363.2014.935232
[5] Johnson M P 2007 Planning models for the provision of affordable housing Environment and Planning B: Planning and Design 34 501-23 DOI: 10.1068/b31165
[6] Thomson C N and Hardin P 2000 Remote Sensing/GIS Integration to Identify Potential Low-income Housing Sites Cities 17 97-109 DOI: 10.1016/S0264-2751(00)00005-6
[7] Zhu X, Liu S and Yeow M 2006 Accessibility Analysis for Housing Development in Singapore with GIS and Multicriteria Analysis Methods Applied GIS 2 13.1-13.12 DOI: 10.2104/ag060013
[8] Yin L and Muller B 2007 Residential location and the biophysical environment: Exurban development agents in a heterogeneous landscape Environment and Planning B: Planning and Design 34 279-95 DOI: 10.1068/b31182
[9] Johnson M P 2001 Tenant-based subsidized housing location planning under uncertainty "Socio-
Economic Planning Sciences" 35 149–73 DOI: 10.1016/S0038-0121(01)00003-9
[10] Johnson M P and Hurter A P 1998 An optimization model for location of subsidized housing in
metropolitan areas "Location Science" 6 257-79 https://doi.org/10.1016/S0966-
8349(98)00044-8
[11] CIFOR 1999 "Guidelines for Applying Multi-Criteria Analysis to the Assessment of Criteria and
Indicators" (Jakarta: CIFOR)
[12] Malczewski J 1999 "GIS and Multicriteria Decision Analysis" (Toronto: John Wiley & Sons, Inc.)
p 387
[13] Malczewski J 2006 Ordered weighted averaging with fuzzy quantifiers: GIS-based multicriteria
evaluation for land-use suitability analysis "International Journal of Applied Earth
Observation and Geoinformation" 8 270–7 DOI: 10.1016/j.jag.2006.01.003
[14] US Census Bureau 2016 "2011-2015 American Community Survey 5-year Estimates" [online]
available at https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?src=bkmk
accessed 09-01-2020
[15] Giap D H, Yi Y and Yakupitiyage A 2005 GIS for land evaluation of shrimp farming in
Haiphong, Vietnam "Ocean and Coastal Management" 48 51-63
[16] Deng L 2007 Comparing the Effects of Housing Vouchers and Low-Income Housing Tax
Credits on Neighborhood Integration and School Quality "Journal of Planning Education and
Research" 27 20-35 DOI: 10.1177/0739456X07301467
[17] Talen E and Anselin L 1998 Assessing Spatial Equity: An Evaluation of Measures of
Accessibility to Public Playgrounds "Environment and Planning A: Economy and Space" 30
595-613 https://doi.org/10.1068/a300595
[18] Deng L 2011 Low-Income Housing Tax Credit Developments and Neighborhood Change: A
Case Study of Miami-Dade County "Housing Studies" 26 867-95 DOI:
10.1080/02673037.2011.593130