GIS-based Suitability Analysis for Siting Waterfront Park in the City of Buffalo, New York

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Abstract. This study utilized GIS-based suitability analysis for selecting potential areas for a waterfront park and recreation facility development in the city of Buffalo, New York. The overall objective of this study was to determine areas which were suitable for new waterfront recreation facility by taking into consideration the multi-criteria set in GIS-based suitability analysis. Among the criteria incorporated in the analysis were a close distance to a waterbody, low density of existing water-based park or splash pads, small cost-distance to the nearest existing water-based park or splash pads, high population change of children per block-group (standardized), low density of existing parks/recreational facilities, and flat landscape slope. For each criterion, raster-based derived map was produced using ArcMap software. The GIS spatial analysis tools utilized to yield the derived maps were a measurement of distance, density calculation, surface analysis, and raster-based statistical analysis. The weighting of each criterion was based on current literature. The derived maps were overlaid and calculated in GIS-raster environment. The resulting composite suitability map shows the areas with higher raster scores as the most suitable sites for future potential waterfront recreation development. As a result, this study had identified four candidate locations which had the highest suitability score. Caution must be exercised in interpreting the results, due to some subjectivity issues in the GIS-suitability analysis, namely in selecting, reclassifying, and weighting the criteria. Nevertheless, this method could assist Buffalo city government in the decision-making process to identify potential locations for future waterfront park/recreation facility in the city of Buffalo.

1. Introduction
This study provides an analysis of the suitability of areas for potential waterfront park or waterfront recreation facility development in the city of Buffalo, New York. The overall objective of this study was to determine areas suitable for potential new waterfront recreation facility development consistent with the opportunities and constraints of the area using Geographic Information System (GIS) suitability analysis. This method could assist the city government in the decision-making process to identify potential recreation facility locations in the city of Buffalo. Furthermore, the shortlisted potential locations identified by GIS suitability analysis can be further examined by detailed site observation.

Located adjacent to Lake Erie and Niagara River, Buffalo is a waterfront city. Spaces at the waterfront or lake shoreline possess good potentials as recreational areas, especially for children. One particular recreation park which is not adequately present in Buffalo is water-related recreation facility for children, such as an outdoor wading pool or splash pads. At the splash pads, children and family can have fun and play with water. This potentially could reconnect the community with the water and water-
based recreation park. Especially in the summer time, there is a need for additional waterfront park in Buffalo.

Prior to conducting spatial multi-criteria analysis in this study, some description of current condition and assumptions are taken into consideration. One specific water-based recreation for children in the summer is water playgrounds, wading pools, splash pads, or spray parks. A splash pad or wading pool is a recreation area, often in a public park, for water play that has little or no standing water. The proposed waterfront park should complement with the City’s waterfront plans and Niagara River Greenway Plan. This should also comply with the standards of outdoor recreation facility set by American Society of Planning Officials Report No. 194 [1]. As an element of the City's water conservation effort, local county government encourages people to use public wading pools and splash pads/spray parks rather than fill their home "kiddy pools" or run backyard sprinklers [2]. This outdoor water playground can be a place for recreation in the summer and bring the community together. This study assumes that Buffalo needs one additional splash pad at the open space connected to water to be developed near the waterfront area. Another assumption is this waterfront park will be owned by the New York State Office of Parks, Recreation, and Historic Preservation (NYS PARKS), but operated by the city through a use permit. Currently, there are 12 wading pools/splash pads area in the city of Buffalo. Mostly they are located in the current public park [3].

2. Methods

GIS-based multi-criteria suitability analysis was used to identify potential locations for the water-based park by incorporating various criteria. The criteria incorporated in the GIS-suitability analysis were: 1) Distance to waterbody (river/lake), 2) Density of existing water-based park or splash pads, 3) Cost distance to the nearest existing water-based park or splash pad, 4) Population change of children under 14 years per block group (standardized), 5) Density of existing parks/recreational facilities, and 6) Slope.

GIS suitability analysis incorporated several steps in the data collection, preparation, and analysis process. The flowchart of suitability analysis steps is depicted in Figure 1.

![Flowchart of suitability analysis steps](image)
2.1. Data gathering method

This study had collected several data sets (raw data) from secondary sources. Census data was collected from United States Census Bureau and downloaded through American FactFinder [4,5]. The census data used was American Community Survey (ACS) 5 years estimate for the year of 2015. Location of existing splash pads data was collected from the City of Buffalo. The digital elevation map (DEM) was downloaded from geo community’s website [6]. The location of ex-brownfields was downloaded from NYS Department of Environment [7]. Furthermore, the raw data are processed to create variables (derived data) according to those criteria set earlier.

2.1.1. Data preparation and processing. After data collection, the next steps are assembling datasets and create the derived data for further analysis. GIS software (ArcMap) with spatial analysis extension was used to prepare the data and perform the spatial analysis. The functionality to measure Euclidean distance was used to measure the distance to waterfront. The density analysis in the spatial analysis extension was used to measure the raster-based density. Surface analysis in spatial analysis was utilized to create raster-based surface based on Digital Elevation Model (DEM). Cost distance functionality was calculated to incorporate the distance and the cost (measured by speed and travel time) to travel through the road network. The children population change was also incorporated in the analysis and calculated in GIS raster environment. Table 1 depicts the data processing and analysis method.

| Criteria | Justification of Criteria | Raw data | Derived data |
|----------|---------------------------|----------|--------------|
| 1 Distance to waterfront (waterbody) | The location of new splash pad is preferably close to waterfront (Erie lakefront and riverfront) to suit the waterfront theme | Polygon data of Erie lake shoreline, rivers, and waterbody | Euclidean distance from lake shoreline and river |
| 2 Density of existing splash pads | New splash pads will be not located in the neighborhood which has high density of existing facility | Point data of existing location of wading pool and splash pads | Density map of existing splash pads (global statistics) |
| 3 Cost distance to the nearest existing splash pads | New splash pads will be located in the areas with the highest cost distance to existing splash pads | Point data of existing location of wading pool and splash pads | Calculated cost distance map to the nearest splash pads |
| 4 Standardized Population change of children under 14 years per block group | New splash pad will be located in the block group with high standardized change of population under 14 years from 2000-2015 | Population data in census tract from decennial census data 2000 and ACS 2015 | Standardized change of population of children in the block group |
| 5 Density of existing parks and recreational areas | New splash pads will be not located in the neighborhood which has high number of existing facility | Point data of existing location of parks and recreational facilities | Total number of parks and recreational facilities in the block group (zonal statistics) |
| 6 Slope | New splash pads will be located in the areas with gentle slope | DEM (elevation map) | Slope map |

The data processing method to create each criteria map were:

a. The process to create density and distance measures.
   - The process to create distance map (distance from waterfront).
   - The process to create density map (dot density of current water-based recreation facilities).

b. The process to create the surface analysis maps
   - Slope map were created from the Digital Elevation Map of Buffalo. Spatial analysis extension allowed to do the conversion from DEM to slope (in percent).

c. The process to create raster surface from grid-based statistics (local and focal statistics).
   - Local statistics
Visualize children population (population 0-14 years old) in American Community Survey 2015’s population data and the Decennial Census 2000’s population data (DC 2000) in the scale of block-group.

Create raster maps of population under 14yr for ACS 2015 and DC 2000.

Calculate population change from 2000-2015 using cell statistics (local statistics: standardized change of population under 14 years).

- Zonal statistics

  Calculate the number of existing splash pads contained in each block group and generate the zonal calculation result in raster map.

### 2.2. Data analysis method

Data analysis method included the process of criteria map reclassification, criteria weighting, and final raster map calculation.

#### 2.2.1. Data reclassification

In the raster map reclassifying process, each derived map had to be reclassified. In the weighting process, the weight of each criterion was set. In this process, I did the reclassification and weighting. The reclassification and weighting were mostly based on prior literature. Then, with that weight assigned for each criterion, the raster calculator using map algebra was conducted. The derived datasets, reclassification and the weighting of criteria from the aforementioned process were depicted in Table 2.

| No | Criteria                                             | Derived data                                                | Old value classification | Value Reclassify | Criteria Weight | Justification of Reclassify/Weight                      |
|----|------------------------------------------------------|-------------------------------------------------------------|--------------------------|------------------|-----------------|---------------------------------------------------------|
| 1  | Distance to waterbody (river/lake)                   | Euclidean distance to Lake Erie shoreline and river         | 0-1000                   | 5                | 0.30            | The State of California The Resources Agency Department of Water Resources (2014) [8] |
|    |                                                      |                                                             | 1001-2000                | 4                |                 |                                                         |
|    |                                                      |                                                             | 2001-3000                | 3                |                 |                                                         |
|    |                                                      |                                                             | 3001-4000                | 2                |                 |                                                         |
|    |                                                      |                                                             | 4001-6000                | 1                |                 |                                                         |
| 2  | Density of existing splash pads                      | Density map of existing splash pads (global statistics)     | 0.0-0.10                 | 5                | 0.15            | Expert judgment based on City of Buffalo standard (2017) and American Society of Planning Officials (1965) |
|    |                                                      |                                                             | 0.11-0.20                | 4                |                 |                                                         |
|    |                                                      |                                                             | 0.21-0.30                | 3                |                 |                                                         |
|    |                                                      |                                                             | 0.31-0.4                 | 2                |                 |                                                         |
|    |                                                      |                                                             | 0.41-0.8                 | 1                |                 |                                                         |
| 3  | Cost distance to the nearest existing splash pads    | Calculated cost distance map to the nearest splash pads     | 0-20,000                 | 1                | 0.15            | Expert judgment based on City of Buffalo (2017).        |
|    |                                                      |                                                             | 20,000-40,000            | 2                |                 |                                                         |
|    |                                                      |                                                             | 40,000-60,000            | 3                |                 |                                                         |
|    |                                                      |                                                             | 60,000-80,000            | 4                |                 |                                                         |
|    |                                                      |                                                             | 80,000-120,000           | 5                |                 |                                                         |
| 4  | Standardized population change of children under 14 years per block group | Change of population of children in the block group standardized by city average | -21 - -6                | 1                | 0.20            | American Society of Planning Officials Report No. 194 (1965) |
|    |                                                      |                                                             | -5.9 - 0                 | 2                |                 |                                                         |
|    |                                                      |                                                             | 0.1 - 6                  | 3                |                 |                                                         |
|    |                                                      |                                                             | 6.1 - 12                 | 4                |                 |                                                         |
|    |                                                      |                                                             | 12.1 - 21                | 5                |                 |                                                         |
| 5  | Density of existing parks/recreational facilities   | Number of parks and recreation facilities in the block group | 0-30                     | 5                | 0.15            | American Society of Planning Officials Report No. 194 (1965) |
|    |                                                      | (zonal statistics)                                          | 31-90                    | 4                |                 |                                                         |
|    |                                                      |                                                             | 91-180                   | 3                |                 |                                                         |
|    |                                                      |                                                             | 181-360                  | 2                |                 |                                                         |
|    |                                                      |                                                             | 360-720                  | 1                |                 |                                                         |
Table 2. Cont.

| Slope map | Slope range | Weight |
|-----------|-------------|--------|
| 0-10%     | 5           | 0.05   |
| 11-20%    | 4           |        |
| 21-30%    | 3           |        |
| 31-40%    | 2           |        |
| 41-50%    | 1           |        |

2.2.2. Combining criteria and creating final map. All criteria which had been reclassified were combined and calculated based on each assigned weight.

The reclassified derived maps were overlaid to develop a composite suitability map depicting areas of very suitable (5), suitable (4), moderate (3), unsuitable (2), and very unsuitable (1) recreation waterfront site development suitability. The resulting composite suitability map showed the areas (in raster pixels) with higher scores as the most suitable sites for future potential waterfront recreation development.

Finally, the final suitability map was clipped to the map of ex-brownfield sites. These ex-brownfields sites were under the DEC Brownfield Clean-up Program. In this program, the private sector is encouraged to clean up the sites to redevelop urban ex-brownfields and revitalize economically blighted community [7].

3. Results

The resulted maps were depicted in the following figures. The maps presented in Figure 2 were the derived maps resulted from the data preparation process from each criterion. The maps presented in Figure 3 were the reclassified maps resulted from reclassifying the derived maps from each criterion. Figure 4 depicted the final raster suitability map with details zoomed in to the areas with the highest suitability scores (very suitable). These raster areas were shown in the darker green color.
As findings of this analysis, there were locations which have high suitability (score 6-7) in the final map selected by this multi-criteria method (refer to figure 4). Those with darker green colors were the areas with high suitability score and potential to be selected to site the water-based park. Zooming in to the highest suitability areas and incorporating the ex-brownfield sites (light green polygons in the map),
there were four potential sites highlighted. Due to the constraint of brevity in this paper, the highest two potential ex-brownfield locations for locating waterfront park to be discussed in this paper were:

1. A strip of sites 990-1050-1088-1130 Niagara Street along the waterfront of Niagara River/Erie Lake with a total area of 11,036 m² and 10,604 m² (refer to figure 4 onset 1).
2. Sites 399 Ohio Street (23,492 m²) and 300 Ohio Street with the area of 19,136 m², adjacent to Conway Park Recreation Point and Buffalo River (refer to figure 4 onset 2).

Based on the findings, the sites adjacent to Niagara River/Lake Erie was the most preferable. The link to Erie lake was established visually. These sites can have connectivity to nearby Broderick park across Black Rock canal. The sites adjacent to Louisiana Park and Recreation Point was preferable compared to the previous one. The waterfront park with splash pads could be an expansion of this existing Louisiana park. This would ensure that the proposed waterfront park will have a connecting hub with current recreational activities in the open space. The sites were also adjacent to a waterbody (Buffalo river) and provided no obstructed view as well as direct physical link to the water.

4. Discussion and conclusion
GIS-based multi criteria analysis was utilized in this study to assist the site selection process for siting the water-based park. GIS and its spatial analysis functionality had been proven its capability in doing so. However, GIS-based multi criteria spatial analysis was not free from subjectivity. This was noted as a limitation to this study, thus, caveats in interpreting the results of GIS-based multi-criteria analysis must be also taken. Caution must be exercised in the interpretation, this was due to potential bias in the criteria selection, map reclassification, and criteria weighting process. Different way of reclassifying and weighting might result in different final suitability map. Therefore, consensus in selecting criteria, reclassifying process, and assigning the weights were crucial.

For further study, the incorporation of more objective weighting process will be needed to increase the objectivity in GIS multi-criteria spatial analysis. This can be done using Analytical Hierarchical Process (AHP), expert judgment, questionnaire, or citizen’s consensus are among the ways to make this weight in multi-criteria analysis improved and more justified. After resulted in the narrowed down list of locations, site observation needs to be conducted for final site selection.

As a conclusion, GIS-based suitability analysis to select a location to site waterfront park for splash pads has assisted the planner in the decision-making process by incorporating multi-criteria. The GIS-based multi-criteria analysis allows incorporation of many variables into the considerations. This method will also applicable in various urban planning fields which incorporates various criteria consideration which were spatially related.

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References
[1] American Society of Planning Officials 1965 *Standards for Outdoor Recreational Areas Report No. 194* Retrieved from: https://planning-org-uploaded-media.s3.amazonaws.com/legacy_resources/pas/at60/pdf/report194.pdf
[2] Seattle Government 2016 *Seattle Parks and Recreation* Retrieved on 29 March 2017, from http://www.seattle.gov/parks/find/spray-parks-and-wading-pools
[3] City of Buffalo 2017 *Public Pool and Ice Skating Rink Information* Buffalo, NY: City of Buffalo, Office of Mayor Byron Brown Retrieved on 27 March 2017, 2017, from https://www.ci.buffalo.ny.us/files/1_2_1/city_departments/public_works_and_streets/parks/pdfs/MapPoolsSplashPads2.pdf.
[4] United States Census Bureau 2017 “P12 : Sex by Age.” *2000 Census*. U.S. Census Bureau, 2000. Accessed through American FactFinder on 11 April 2017. http://factfinder2.census.gov.
[5] United States Census Bureau 2017 *Population, 2011-2015 American Community Survey 5-year estimates* Retrieved from http://factfinder2.census.gov.
[6] GeoCommunity 2017 United States Geological Survey DEM. Website http://www.geocomm.com
[7] New York State Department of Environmental Conservation 2017 *Brownfield Clean-up Program* Retrieved on 27 March 2017, 2017, from http://www.dec.ny.gov/chemical/8450.html
[8] The State of California The Resources Agency Department of Water Resources 2014 *Recreation Suitability Analysis Oroville Facilities Relicensing FERC Project No. 2100*