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Title	Multi-objective Facility Location Modeling: A case study on parks and open spaces

(800 words)

All densely populated developing cities in the world are confronted with a big challenge in the planning of urban parks and open spaces (POSs). For rapid urbanization of such a densely city Dhaka, different activities are developing. It is creating enormous pressure to maximize floor area, squeezing open space out of the urban landscape. Therefore, it is utmost important to analyze the existing conditions of POSs in Dhaka and develop a modeling tool that can accurately predict and place necessary POSs in the city. Genetic algorithms (GAs) are a popular meta-heuristic as by maintaining a population of solutions, they can search for many non-inferior solutions in parallel. GAs are used to solve multiple objective problems in various applications. However, none of these GA-based multi-objective optimization models has yet been used for POSs location planning.

At first detail analysis have been conducted on the locations and existing condition of POSs in the problem study area (Dhaka city) comprised of 90 wards. For this analysis, widely used softwares like ArcGIS, SIS and Erdas Imagine are used. It is concluded that existing POSs are unevenly distributed and rather concentrated in a few places. It is found that only 0.22 acre of POSs is available per 1,000 population which is far below the standard. It is suggested to provide more POSs to attain better environment by developing a multi-objective model.

Next, new GA-based models were developed to address in general continuous facility location problems i.e. p-median problems. Two new GA-based models (GA1 and GA2) and two hybrid methods (HGA1 and HGA2) were developed for the problem. The GA-based methods were developed by modifying the replacement procedure of the original GA. The hybrid methods made use of alternating location-allocation method to avoid a very long computation time to reach the best solution. The performance of these new heuristics was compared with the original GA and with the traditional alternating location-allocation method. It was found that the performance of new methods is better than traditional methods with respect to both the solution quality and the computational efficiency.

A new GA-based model (GA1) is then extended to tackle multi-objective problem for urban POSs planning. The model was developed to take four incommensurable objective functions into account: minimizing the distances from 1) POSs to highly populated areas, 2) POSs to areas with high air pollution, 3) POSs to noisy areas, and 4) POSs to areas without POSs. The model was coded in the C++ programming language and first tested with random data sets. Finally, the model was executed with real data sets from the city of Dhaka as a case study. The potential differences between optimizing single objective functions and multi-objective function are highlighted. To guarantee a Pareto front using a multi-objective operator, a dynamic weighting scheme was used to combine multiple objectives into a single one. The different executed experiments have proved that the algorithm successfully finds non-dominated Pareto optimal solutions, derives the Pareto front and thereby provides decision makers with a set of alternative solutions.

From the practical applications point of view POSs location problems are of course challenging as some regions called barriers in the problem space are to be excluded for the placement of new facilities. The developed multi-objective model was further extended to include such barrier constraints. The considered barriers include fixed circular barriers (such as existing parks, industrial areas, and market areas), flexible circular barriers (water bodies) and line barriers (lakes). The fixed circular barriers are the regions where neither facility location nor distance is permitted, the flexible circular barriers are the regions where facility location is restricted but distance is allowed to trespass, and the line barriers are the regions where facility location is not allowed but distance is allowed only through some entry passages i.e. over bridges. The model was successful to place new POSs excluding barriers in Dhaka city.

In practice, urban POSs are of various types and sizes. To address this issue, finally the model was modified for optimum locations of multi-variant POSs. Six objective criteria were chosen: population, air quality, noise level, air temperature, water quality and recreational value. A new allocation decision variable was used in the objective function of the model considering the existing barriers for locating new multi-variant POSs. Suitable locations for each type of new multi-variant POS locations were established by the use of proximity analysis function of geographical information system (GIS). The model has successfully generated new multi-variant POSs.

In gist, new GA-based multi-objective optimization models were developed and applied to problems of facility locations particularly for urban POSs by considering many incommensurable objective functions into account. The multi-objective modeling thus suggest how multi-objective POS location methods can be used by city planning authorities to design and manage POSs to maintain a sustainable environment and better quality of life in a city.