Development of a Spatial Multi Objective Optimization Model for Intensive Energy Industries Land Use Planning

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Introduction

Land use planning is the process of allocating different land uses and activities to the special land units. By considering the role of industries in development, employment and environment, in this paper industrial and especially intensive energy industries' planning was considered as a multi objective optimization problem. Although, during the last decades linear programming was used for solving this problem, recent researches trends to use evolutionary algorithms. NSGA-II method has been used in this paper. In this paper Isfahan province has been considered as the case study area. Isfahan, because of its geographical location and infrastructural facilities has been one of the industrial poles. Various data such as main roads, railroads, mines, power transmission lines, gas transmission lines, rivers, faults, lakes, city regions, sensitive ecological areas have been used as factor maps to locate industrial site.

Methodology

In this paper, some steps have been taken to utilize NSGA-II:

Define environmental constraints: with the consideration of the environmental rules, unsuitable areas were removed from the case study. Some buffers around roads, forests, rivers, faults and conservation areas were created. Therefore, these areas were removed from the next steps.

Encode candidate solutions: For each pixel a number as index was assigned that formed the chromosomes of our problem.

Initial population: Initial population is created randomly from indexes. In this paper we considered 25 solutions as the initial population. Each individual corresponds to one candidate solution (decision alternatives).

Fitness functions: In this study, minimized distance (d_c) from population centers was considered as social objective and maximized distance from water resources (d_w), forests (d_f) and protected natural areas (d_p) was considered as environmental objective.

- $\text{Social objective} \approx Min((1/population\_density) \times d_c)$
- $\text{Environmental objective} \approx 1/\min(\sum(d_f + d_p + dw))$

Results

In this paper real coded decision variable, simulation binary crossover and polynomial mutation were used. NSGA-II in different generations was run and optimum results were obtained in 1000th generation. Most of the selected areas are located in Khor, Anarak and Niasar districts.

After obtaining the results of NSGA-II based on both social and environmental objectives, economical objective was used to determine the priority of each selected locations to allocate to iron, aluminum and cement industries (Figure 1).

For Iron and steel industry: Economic objective~ *Min* ((1/25.91)*d_r + (1/21.17)*d_m + (1/40.87)*d_e + (1/12.05)*d_g),

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For Cement industry: Economic objective~ $Min\ ((1/18.8)*\ d_r + (1/17.45)*\ d_m + (1/21.14)*\ d_e + (1/42.61)*\ d_g)$,
For Aluminum industry: Economic objective~ $Min\ ((1/17.8)*\ d_r + (1/16.67)*\ d_m + (1/28.41)*\ d_e + (1/37.12)*\ d_g)$
Where:
d_m: direct distance between each selected location (pixel) and location of mines.
d_r: direct distance between each selected location (pixel) and closest road.
d_e: direct distance between each selected location (pixel) and closest power transmission line.
d_g: direct distance between each selected location (pixel) and closest gas transmission line.

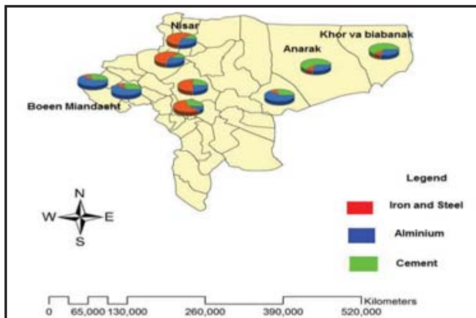

Fig.2: Prioritization of locating industries

Evaluation of the results

Stability, Generation and population numbers of the algorithm have been tested and the results have been verified. For proving the stability of algorithm, the algorithm was repeated 4 times with 25 initial solutions and 50 generations. The results showed no significant scientific differences among them (Figure 2).

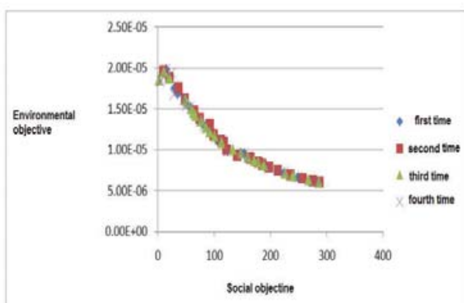

Fig.3: The results of iterating algorithm

NSGA-II with different generations and population numbers was run. Figure 3 illustrates that better solutions were obtained with increasing the generation or population.

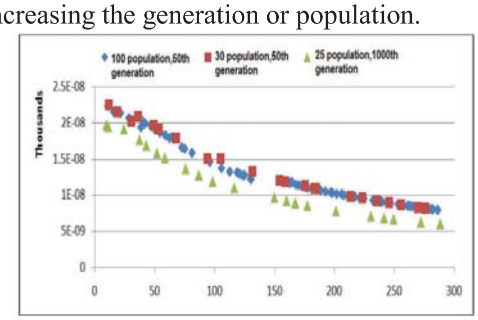

Fig.4: Improvement of the results with increscent of generation or population numbers

For verifying the results, NSGA-II was applied for the whole pixels to obtain Pareto front. First front was used to compare the results with 1000th generation. This comparison shows that the result of 1000th generation is matched with Pareto front (Figure 4). To verify the result of allocating the resulted locations from NSGA-II to different industries, weighted overlay method was used in GIS environment and the results show 66% overlap for locations with first priority.

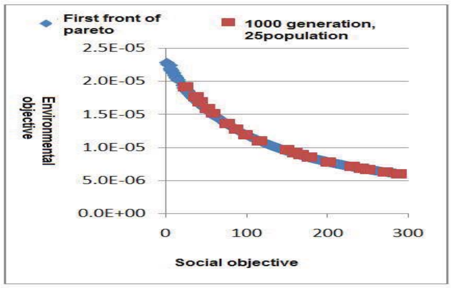

Fig.1: Comparison of the results of 1000th generation with Pareto front

Conclusion

Spatial Land use planning activities should consider the economical, human resources and ecological characteristics of lands based on a sustainable development perspective. This has relationship with economical, social and environmental objectives. Therefore, it is a multi objective optimization problem. Investigation of multi objective optimization methods shows that evolutionary algorithms are efficient for solving these problems. The paper presents a spatial multi objective optimization model based on NSGA-II for site selection of intensive energy industries. NSGA-II was run with 25 initial populations in different generations until proper Pareto front was obtained using of social and environmental objectives in 1000th generation. Next, priority of resulted locations (pixels) was determined for allocating to various industries based on economical factors. The results show that with running NSGA-II it is possible to find optimum solutions, evaluate these solutions in details and finally support decision maker activities. The characteristics of the utilized model is having spatial dimension in all steps of the model including putting constraints and objectives. Also, it prevents losing good solutions with finding trade off between objectives.

For further studies, we suggest to consider more criteria such as wind direction, distance from existing industries, operating cost etc for modeling and implement other evolutionary algorithms and compare the results.

Key words

Multi objective optimization, Land use planning, Intensive energy industries, GIS, NSGA-II