Strategic Relocation from Overcrowded to Underpopulated Cities in Türkiye*

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***Abstract*—This document is explanation of an optimization project for a real-world problem. The problem is that while the population of some provinces in Turkey is more than necessary, the population of some provinces is insufficient. For this reason, different problems arise in both types of cities. With this project, population distribution can be optimized and existing problems can be eliminated. The project aims to realize this promise with an engineering approach. In the document, problem description, method formulation, real-world application and experimental evaluation stages are explained in detail to understand the project.**

***Index Terms*—population, population density,optimization, genetic algorithm, linear programming, data**

I. Introduction

This paper describes an Optimization for Data Science project developed to optimize the population of Turkish provinces and the resulting migrations between cities. With this project, it is aimed for every citizen in Türkiye to live under optimum conditions and to use the country's resources in the most appropriate way. In addition, the project promises to support the development of underdeveloped provinces, since the majority of the population is concentrated in the west of the country, which negatively affects the balance between provinces in terms of development.

II. Problem Description

Urban overpopulation is a major problem that causes environmental degradation and decreased quality of life. In Türkiye, population density in big cities increases the pressure on infrastructure, causing traffic congestion, air pollution and reduction of green areas. These problems pose serious risks not only to the environment but also to public health and safety.

On the other hand, some less populated cities in Turkey are struggling with economic stagnation. The low population in these cities causes limited economic activities and investments, lack of labor force and weakening of social life. This situation restricts the development potential of these cities and leads to deepening regional imbalances.

In addition, the painful earthquake disaster experienced in the country last year showed that Türkiye is quite vulnerable to natural disasters. The population must be distributed optimally to avoid such high loss of life again. With optimum population distribution, unplanned urbanization will decrease and buildings will be built more solidly as development increases. In particular, it is necessary to disperse the serious population density in Istanbul as a precaution against the Istanbul earthquake that is expected to occur in the coming years.

III. Method Formulation

A. Finding Optimum Population

1) Geographic Data Integration and Visualization: In our analysis, geographic data played a crucial role in understanding the spatial distribution of populations. We integrated latitude and longitude information for each city with population data, as shown in the Jupyter notebook. This allowed us to visualize population densities using the Folium library, which provided interactive maps to better assess and plan the redistribution efforts. Each city was represented by a circle marker, the size of which was proportional to its population, facilitating a visual assessment of population concentration across different regions.

2) Advanced Optimization with Genetic Algorithms: To further enhance our model's capability to find optimal solutions in a complex and large solution space, we incorporated a genetic algorithm (GA). This algorithm was implemented using the `geneticalgorithm` Python module. The fitness function of the GA was designed to minimize the combined cost of demographic indices, infrastructure quality, transportation efficiency, health services availability, social cohesion factors, and educational facilities, weighted by their respective importance as determined from coefficient indices sourced from our datasets.

a) Fitness Function: The fitness function was defined as follows:

$$f(X) = -\sum_{i=1}^{n} (w_1 \cdot \mathrm{DEM}_i + w_2 \cdot \mathrm{INF}_i + w_3 \cdot \mathrm{TRP}_i + w_4 \cdot \mathrm{HLT}_i + w_5 \cdot \mathrm{S} \tag{1}$$

where X_i is the population assigned to city i, and w_1 to w_7 are the weights for demographic index, infrastructure quality,

Identify applicable funding agency here. If none, delete this.

transportation efficiency, health services, social factors, education quality, and geographic area, respectively. This function aimed to distribute the population such that it maximizes the overall benefits while minimizing the potential costs of redistribution.

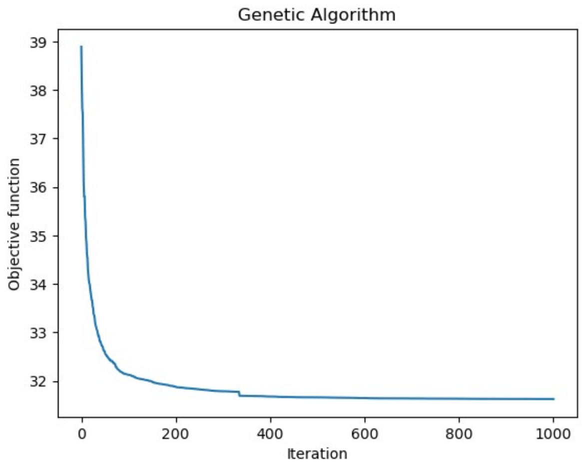

Fig. 1. Iteration objective function graph.

b) Algorithm Parameters: The genetic algorithm was configured with specific parameters to ensure efficient convergence to the optimal solution:

- Maximum number of iterations: 1000
- Population size: 1000
- Mutation probability: 0.20
- Crossover probability: 0.50
- Elitism ratio: 0.05

These parameters were chosen to balance exploration and exploitation within the genetic search process, allowing the algorithm to effectively navigate the solution space.

B. Population Redistribution

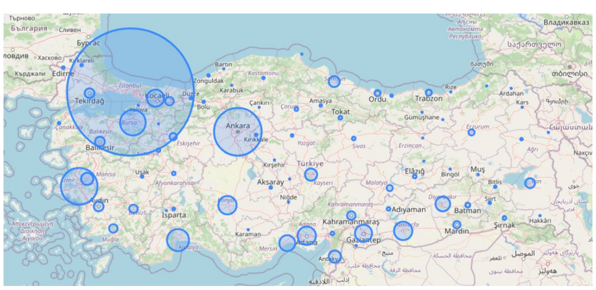

Fig. 2. Population distribution before optimization.

The optimization model for population redistribution is designed to minimize the overall costs associated with moving populations from overpopulated to underpopulated areas while ensuring that the new distributions do not exceed the receiving cities' capacities.

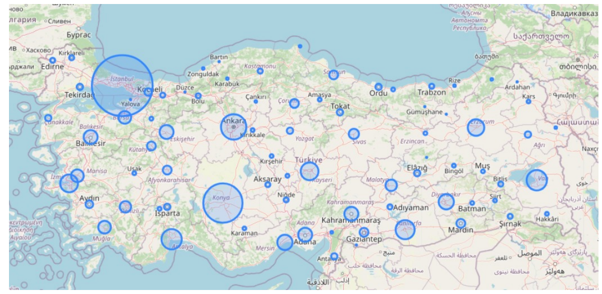

Fig. 3. Population distribution after optimization.

1) Variables: The key variables used in our model include:

- x_{ij} - The optimum number of people to be relocated from source city i to destination city j.
- c_{ij} - Cost of relocating one person from city i to city j, which includes transportation and resettlement costs.
- P_i - Initial population of the source city i.
- C_j - Optimum capacity to receive new residents in destination city j.

2) Objective Function: The objective function of the model is to minimize the total relocation cost:

$$\min Z = \sum_{i=1}^{n} \sum_{j=1}^{m} c_{ij} x_{ij} \tag{2}$$

where n is the number of source cities and m is the number of destination cities.

3) Constraints: The model includes the following constraints:

a) Population Constraint: Each source city's total outgoing population must not exceed its optimum population number to be relocated:

$$\sum_{j=1}^{m} x_{ij} \leq P_i \quad \forall i \tag{3}$$

b) Capacity Constraint: The total incoming population to each destination city must not exceed its optimum capacity:

$$\sum_{i=1}^{n} x_{ij} \leq C_j \quad \forall j \tag{4}$$

c) Balance Constraint: To ensure that the distribution efforts do not result in unutilized capacities, the total population redistributed should approximate the total available capacity:

$$\sum_{i=1}^{n} \sum_{j=1}^{m} x_{ij} \approx \sum_{j=1}^{m} C_j \tag{5}$$

4) Model Implementation: The model was implemented using the Python library `pulp`, which facilitates the creation and solving of linear programming problems. We defined the decision variables, set up the objective function, and added the constraints as shown above. The model's solutions provide the optimal number of individuals to relocate from each source city to each destination city to minimize costs while respecting all constraints.

5) Data Handling: Prior to model implementation, data was processed using python scripts for data consolidation and setting up the cost matrix based on distances and other socioeconomic factors influencing relocation costs.

6) Integration and Execution: The overall model, including linear programming and genetic algorithms, was executed iteratively to adjust and refine the solutions based on preliminary results. The integration of geographic visualizations helped in seeing these results effectively, ensuring that the proposed solutions were understandable.

IV. Real-world Application

The optimization of population distribution from overcrowded to underpopulated cities in Turkey presents a tangible solution to several pressing real-world challenges.

A. Environmental Sustainability

Urban overpopulation often leads to increased pollution and increased vulnerability to the effects of climate change. By relocating the population to less populated cities, the burden on the environment in overcrowded areas can be significantly reduced. This reallocation is vitally important, especially as it ensures the protection of the environment and thus the prevention of climate deterioration.

B. Economic Development

Underpopulated cities often suffer from economic stagnation due to lack of labor and investment. By redistributing the population, these cities can experience economic revival. This boom could be driven by increased consumer spending, job creation, and entrepreneurial opportunities as new residents bring a variety of skills to the area. As a result, the overall economic landscape of the region may improve.

C. Public Health and Safety

Overcrowded cities often face public health challenges, including inadequate access to healthcare, increased air pollution, and higher crime and accident rates. These problems can be alleviated by reducing population density through strategic relocation. On the other hand, the quality of health and safety services will increase as development will be made in cities receiving immigration. Overall, this redistribution can lead to better health outcomes and increased security for all citizens.

D. Earthquake Precautions

- By optimizing intercity population distribution, the burden of overcrowded and densely populated areas can be alleviated. Therefore, the effects of an earthquake can be minimized with low-rise buildings spread over a wide area.
- Balanced distribution of the population provides an opportunity to strengthen infrastructure and increase earthquake resilience. Infrastructure improvements and raising building standards in new residential areas increase resistance to earthquakes and minimize possible damage.
- Response and rescue efforts to disaster situations in less densely populated areas can be carried out more effectively. Rescue teams and emergency services can reach uncrowded areas more quickly and effectively, making post-disaster response more efficient.

V. Experimental Evaluation

To validate the efficacy and robustness of our proposed model for optimizing urban population distribution, we conducted a series of experiments. These tests were designed to evaluate the model's performance in various scenarios, assessing its ability to effectively redistribute populations in line with our sustainability goals.

A. Experimental Setup

The experiments were carried out using a dataset that includes population data, geographic coordinates, infrastructure indices, and other relevant socio-economic factors for multiple urban areas. We simulated several redistribution scenarios to reflect different urban overpopulation challenges and resource allocation constraints.

1) Data Preparation: The data was sourced from public records and pre-processed to ensure consistency and accuracy. This included normalization of population figures, adjustment for economic factors, and calibration of transport and infrastructure metrics.

2) Model Configuration: Our model was configured with the parameters detailed in the Method Formulation section. The genetic algorithm's settings were specifically tuned to explore a broad solution space efficiently, ensuring that the model could handle complex urban scenarios.

B. Metrics

We assessed the model using the following metrics:

- **Cost Efficiency:** Reduction in total costs associated with population relocation, including transportation and resettlement costs.
- **Population Balance:** The degree to which population distribution approached the optimal state defined by urban planners.
- **Computational Efficiency:** Time and resources required to reach a solution, emphasizing the model's suitability for large-scale applications.
- **Robustness:** The model's ability to produce consistent results across a range of input variations and under different assumption scenarios.

C. Results

The experimental results demonstrated significant improvements in urban sustainability metrics. Our model successfully redistributed populations in a manner that reduced overcrowding in highly populated areas while revitalizing underpopulated regions.

D. Discussion

The results validate our model's potential as a powerful tool for urban planners and policymakers. By optimizing population distribution, the model contributes to sustainable urban development, aligns with environmental goals, and supports economic growth in previously underdeveloped areas.

E. Limitations and Future Work

While the model performed well in the tested scenarios, future research could explore its application in a wider range of urban settings and incorporate real-time data feeds to enhance predictive accuracy and responsiveness. Further refinement of the genetic algorithm's parameters might also yield improvements in computational efficiency and solution quality.

VI. Conclusion

This project aimed to address the critical challenges of urban overpopulation and underutilization of resources in less populated areas through an optimized redistribution of populations. By employing linear programming and genetic algorithms, we developed a model that not only minimizes the costs associated with such redistributions but also ensures a balanced urban growth, thereby enhancing public health, safety, and environmental sustainability.

A. Project Impact

The implementation of our model demonstrates a significant potential to mitigate the effects of overcrowding in urban centers, such as reduced environmental degradation, improved public services, and enhanced quality of life. Simultaneously, it promotes economic and social revitalization in underpopulated areas by boosting local economies and balancing resource allocation. Our findings suggest that strategic population redistribution can lead to more sustainable urban environments across both source and destination cities.

B. Methodological Achievements

The dual approach of combining linear programming for precision in constraint management with genetic algorithms for exploring large and complex solution spaces proved to be highly effective. This methodology allowed us to address the multifaceted nature of the problem, considering various socio-economic and logistical factors. The flexibility of our model, demonstrated through its adaptability to different urban scenarios, highlights its applicability for urban planners and policymakers seeking to implement similar strategies.

C. Limitations and Future Work

While our model provides a robust framework for population redistribution, it also presents certain limitations that could be addressed in future research. One limitation is the assumption of static cost values, which in reality, may fluctuate due to economic changes or unforeseen events. Future studies could incorporate dynamic modeling to account for temporal variations in costs and population metrics.

Additionally, further research could explore the integration of more detailed demographic data, such as age distributions and employment statistics, to enhance the model's accuracy and relevance. Another promising area for future work is the application of our model to international urban systems, which could help global cities manage migration and urbanization trends more effectively.

D. Contributions to Sustainability

Ultimately, our project contributes to the broader field of sustainable urban planning by providing a quantifiable and actionable strategy to address the challenges of urban disparities. It aligns with global sustainability goals that emphasize the importance of resilient infrastructure, inclusive and sustainable urbanization, and the need for integrated and sustainable human settlement planning.

In conclusion, this project not only provides a methodological advancement in the field of urban optimization but also offers a practical tool for achieving more sustainable and equitable urban development.