OPTIMIZATION OF SHELTER PLACEMENT IN POST-DISASTER MANAGEMENT: A GRAPH-THEORETIC APPROACH[1]

Didem Gözüpek

Gebze Technical University, Department of Computer Engineering, Türkiye
e-mail: didem.gozupek@gtu.edu.tr

Natural disasters such as earthquakes often lead to large-scale displacement, necessitating the rapid deployment of temporary shelter settlements. In practice, these settlements, which are commonly realized as container cities, are typically designed with a primary focus on logistical efficiency and rapid installation. However, such approaches frequently overlook a critical dimension: equitable and reliable access to essential services. As a result, residents may face significant barriers in accessing healthcare, sanitation, water, and education facilities, which can negatively impact both well-being and recovery processes.

In this talk, we will first review the relevant literature on shelter allocation and layout design. Most combinatorial optimization studies on shelters in disaster management focus primarily on determining shelter locations and/or assigning survivors to shelters, while largely neglecting the design and layout of shelter sites [1]. Yet, in post-disaster contexts, shelter areas often resemble refugee camps. To address living conditions in such settings, the United Nations Refugee Agency (UNHCR) has developed planning standards [2]. To the best of our knowledge, the only study explicitly addressing the optimization of shelter layout design is [3], where the authors employ a general block design structure to account for facility requirements and their interrelations.

In the first part of this talk, we present a graph-theoretic optimization framework for designing post-disaster shelter layouts that explicitly incorporate human-centric accessibility considerations. Motivated by international humanitarian standards, we model the settlement as a discrete spatial structure and enforce that every residential unit maintains access to all required service types within prescribed walking distances. These requirements are derived from established guidelines such as those provided by UNHCR [2], ensuring practical relevance and policy alignment.

We formulate the problem as an integer linear program that simultaneously maximizes residential capacity and guarantees multi-facility accessibility. The

[1]This work has been supported by the European Commission's Horizon Europe Research and Innovation programme through the Marie Skłodowska-Curie Actions Staff Exchanges (MSCA-SE) under Grant Agreement no.101182819 (COVER: (C)ombinatorial (O)ptimization for (V)ersatile Applications to (E)merging u(R)ban Problems)

model captures several realistic aspects of shelter planning, including heterogeneous facility types, varying service capacities, and spatial constraints on facility formation. In particular, service facilities are represented as groups of adjacent containers satisfying internal cohesion constraints, while each residential unit must be assigned to accessible service groups of all required types. Capacity limitations and exclusivity conditions are incorporated to ensure feasibility and structural consistency. We make a numerical evaluation of our proposed model by conducting computational experiments on large-scale grid-based instances.

In the second part of this talk, we will present a graph theoretic modeling of this problem using singleton rainbow domination. Consider a graph G together with a collection of k colors, where each vertex is assigned any subset of these colors. Such an assignment is called a k-rainbow dominating function if every vertex receiving no color has neighbors whose assigned colors collectively include all k colors. The associated parameter $\gamma_{rk}(G)$ is defined as the minimum total number of colors assigned across all vertices [6]. If we further restrict the assignment so that each vertex receives at most one color, then the concept is known as *rainbow k-domination* [4] (or *singleton rainbow domination*) [5], and the corresponding parameter is denoted by $\tilde{\gamma}_k(G)$. We will present several structural results and bounds on $\tilde{\gamma}_k(G)$ for specific graph classes such as grid graphs.

References

[1] A. Kamyabniya, A. Sauré, F. S. Salman, N. Bénichou, and J. Patrick, "Optimization models for disaster response operations: a literature review," *OR Spectrum*, vol. 46, pp. 737–783, 2024. https://doi.org/10.1007/s00291-024-00750-6.

[2] UNHCR Emergency Handbook, 4th ed., 2026. [Online]. Available: https://emergency.unhcr.org.

[3] O. Karsu, B. Y. Kara, and B. Selvi, "The refugee camp management: A general framework and a unifying decision-making model," *Journal of Humanitarian Logistics and Supply Chain Management*, vol. 9, no. 2, pp. 131–150, 2019.

[4] F. Bonomo, B. Brešar, L. N. Grippo, M. Milanič, and M. D. Safe, "Domination parameters with number 2: Interrelations and algorithmic consequences," *Discrete Applied Mathematics*, vol. 235, pp. 23–50, 2018.

[5] R. Erveš and J. Žerovnik, "On 3-rainbow domination number of generalized Petersen graphs $P(6k, k)$," *Symmetry*, vol. 13, no. 10, Art. no. 1860, 2021.

[6] B. Brešar, M. A. Henning, and D. F. Rall, "Rainbow domination in graphs," *Taiwanese Journal of Mathematics*, pp. 213–225, 2008.