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The "Fuzzy Back-End" of Collaborative R&D Projects
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Sustainable development and environmental planning is increasingly being seen as a major challenge in both local and global terms. Current consumption patterns, along with business and economic activities, constantly increase the amount of solid waste being produced. As such implementing sustainable management solutions for municipal waste is vital for the development of a healthy urban environment. This article briefly reports on a research project for the municipality of Athens. The main focus is on the development of the appropriate mathematical models and algorithms that enable decision makers to address the garbage containers network design problem.

The residential population and all other commercial or non-commercial waste producers of Athens are primarily serviced through a large scale municipal-wide network of geographically scattered garbage containers-bins. These establishments for waste collection consists of two different types of containers; the so-called blue containers that are dedicated for the collection of a large variety of recyclable materials, including paper, plastic, wood, metal and glass, and a common type of containers that are used for the collection of all kinds of solid and organic waste. Due to the fact that the generation rate of recyclable waste has been increased rapidly during the last few years, the major issue arising for the local authorities of the city is how to expand and populate the network of blue containers with simultaneous replacement of common containers in order to cover the current and future needs of the city and to maximize the service quality of the residential population.

The associated service network design problem raises several theoretical and computational research challenges with major social dimensions. The main goal is to find the optimum assignment, location and allocation of containers to street segments such that the walking distance between containers and waste producers is minimized and the ratio between the waste accumulation at each location and the potential storage capacity is maximized. Each resident has a predefined average daily waste production rate and can be service from the containers located either at the street segment he lives or at the street segments directly connected to it, within a predefined maximum walking distance. The total storage capacity of containers of each street segment must be more than or equal to the total waste accumulation rate with respect to the residential population and the corresponding commercial activities of each segment. Finally, one must additionally consider the service needs of particular points of interest (e.g. one blue container outside schools), the actual capability of each street segment to accommodate garbage containers and the total number of available containers of each type.

Rigorous mixed integer linear programming mathematical models have been developed that captures all critical aspects and concerns of the garbage containers network design problem described above. To this end, computationally intelligent solution algorithms equipped with novel artificially intelligent mechanisms were designed, developed and implemented for solving the models. The proposed solution methods proved to be highly efficient and effective to a wide variety of very large-scale data sets assuming different scenarios and specifications. Given the explosive computational complexity and the combinatorial nature of the models, high quality solutions are produced within relatively short computational times. Figure 1 provides a pictorial view of a solution generated for a small district of Athens.

Figure 1: Sample solution. The blue and black dots refer to blue and common containers, respectively. The tension of the colour of each block is analogous to population density. Dark orange colours indicate dense populated blocks, while light yellow colours indicate sparse populated blocks. The red marks indicate points of interest.

The potential impact of Operations Research methods and tools in the wider arena of sustainable development is great, especially when they focus on the social dimensions of waste management. Evidently, the solution approaches designed and implemented in the context of this research project managed to maximize both the service quality and the capacity utilization of the network subject to a number of operational and social constraints. The proposed assignment and allocation of garbage containers covers all current and future service needs of the residential population of Athens and promotes recycling.