May 2010

Towards the Design of Decision-Making Tools for Municipal Waste Collection Services

by Dr Panagiotis P. Repoussis, Senior Research Fellow

Implementation of sustainable solutions for municipal waste collection services is vital for the development of a healthy urban environment. Current consumption patterns, along with business and economic activities, constantly increase the amount of solid waste being produced, especially for the overpopulated city of Athens. Municipal waste in the EU is projected to increase 25% by 2020, while the generation of municipal waste grows faster in the newer member states. For this reason, we consider municipal waste collection, treatment, recycling and disposal as focal coupling processes with significant and wide range environmental and socio-economic impacts [1].

The task of providing waste collection services typically lies with local authorities, and most local government laws give them exclusive ownership over waste and therefore responsibility, once it has been placed outside a residence or an establishment for collection. Generally, the waste collection problem consists of defining a set of multiple collection-disposal route cycles for a fleet of heterogeneous collection vehicles located at multiple depots [1,2]. To this end, each vehicle has a carrying capacity, a waste compressing factor and it is equipped with a crane that elevates the container, empties its content and restores the container to its place. On the other hand, there is a large scale municipal-wide network of geographically scattered containers for the service of the residential population, commercial customers and other waste producers. What complicates matters further is that there are several different types of containers collected separately for different types of waste (e.g. recyclable materials, organic waste, hazardous etc), while the accumulation rates and the actual needs for collection are volatile and stochastic (or unknown in many cases). As such, the daily planning and scheduling of waste collection activities involves a series of decision making processes that raise major challenges.

Considering the city of Athens, all waste producers are serviced through a large scale municipal-wide network of garbage containers-bins. The collection of waste from the network of garbage containers and the transportation of the collected waste to the appropriate disposal facilities (e.g. disposal sites, mechanical recycling sites and recyclable waste treatment sites) is performed via a heterogeneous fleet of waste collection vehicles on a 24/365 basis. From the operational viewpoint, each waste collection vehicle serves a particular set of street segments, called waste collection sectors, assuming two disposal trips with predefined route duration, accessibility and capacity constraints. The goal is first to find the optimum clustering of street segments and assignment of different vehicle types to each sector and second to design minimum cost vehicle routes, i.e., to find the service sequence of garbage containers, such that the utilization of available resources is maximized with the least possible operational cost. Clearly, as most of the waste collection service providing cost comes from transportation and disposal activities, improving efficiency in operating the fleet improves the bottom line.

The aforementioned combined arc-routing sectoring problem constitutes a hard combinatorial optimization problem that raises both theoretical and computational research issues [1,2]. What complicates matters further is the heterogeneous vehicle assignment sub-problem to each waste collection sector due to accessibility restrictions. Given the exact locations of garbage containers, a rigorous mixed integer linear programming mathematical model has been developed that captures all critical aspects and concerns of the problem, including shortest paths and distances between all possible pairs of street segments, vehicle's average speeds, service times, disposal trips duration times, maximum carrying capacities for each vehicle type, available fleet size and composition etc. To this end, a highly sophisticated hybrid optimization method [3,4] is designed and developed for solving the model. Given the explosive computational complexity and the combinatorial nature of the model, high quality solutions are produced with modest computational burdens to a wide variety of very large-scale problem instances, according to a predefined set of the specifications. Figure 1 provides a pictorial view of the solutions generated (waste collection sectors) for the municipality of Athens considering the collection of recyclable materials.

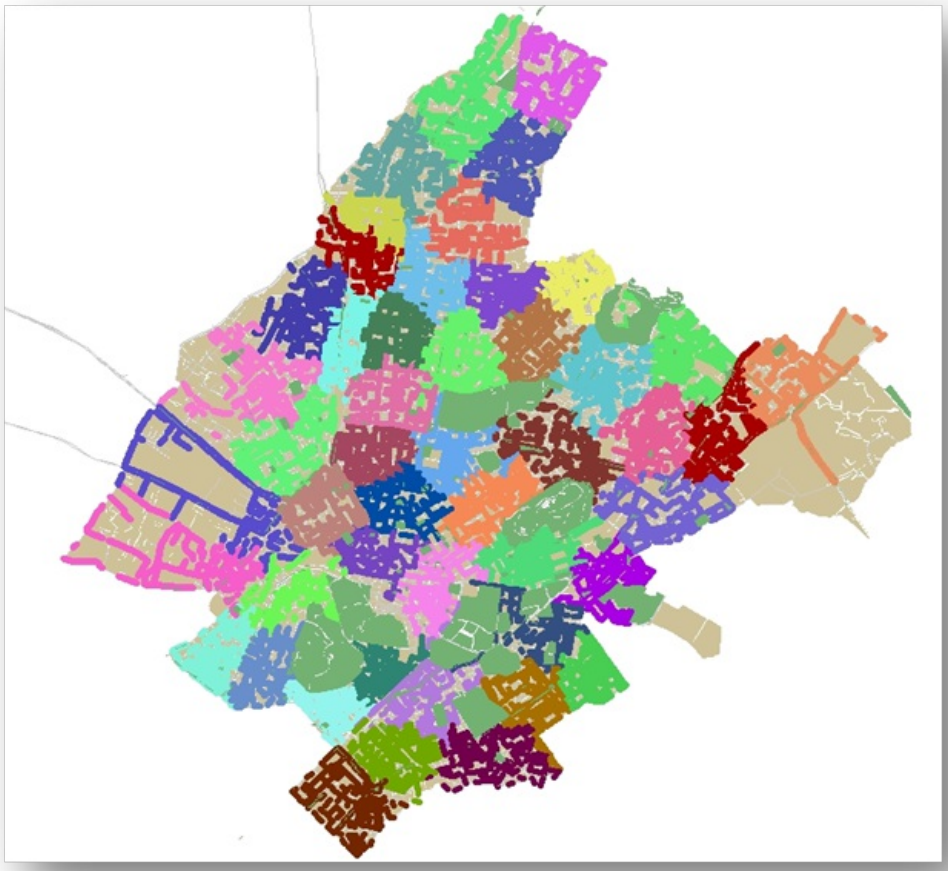

Figure 1: Planned Waste Collection Sectors for the City of Athens.

In conclusion, the potential impact of the application of decision making tools in the wider arena of sustainable development is great, especially when they focus on the social dimensions of waste management [1,5]. The waste collection sectors produced by the proposed optimization method cover the current and future service needs of all waste producers (both residential and commercial) of the city of Athens. To this end, reductions up to 15-25% are estimated, in terms of operational costs, with respect to the current fleet composition and service levels (expressed as network collection frequencies) provided by the municipal authorities.

Indicative Bibliography

[1] Sahoo S., Kim S., Kim B., Kraas B., Popov Jr. A., (2005), Routing Optimization for Waste Management, *INFORMS Interfaces*, 35(1): 24-36.

[2] Mourão M.C., Nunes A.C. and Prins C., (2009), Heuristic methods for the sectoring arc routing problem, *European Journal of Operational Research* 196 (3): 856-868.

[3] Repoussis P.P., Tarantilis C.D. and Ioannou G., (2009), Arc-guided evolutionary algorithm for the vehicle routing problem with time windows, *IEEE Transactions on Evolutionary Computation*, 13(3):624-647.

[4] Tarantilis C.D., (2005), Solving the vehicle routing problem with adaptive memory programming methodology, *Computer and Operations Research*, 32(9):2309-2327.

[5] Repoussis P.P., Paraskevopoulos D.C., Zobolas G., Tarantilis C.D. and Ioannou G., (2009), A Web-based Decision Support System for Waste Lube Oils Collection and Recycling, *European Journal of Operational Research*, 195(3): 676-700.