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An Advanced Solution Approach for Energy Efficient Garbage Collection Service

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Abstract

In recent years, the Municipality of Piraeus has focused efforts on the improvement of efficiencies in the management of waste collection, which constitutes a major activity and involves complex processes such as vehicle routing and scheduling. The overall goal is to establish improved routes for the garbage collection service in an effort to gain significant savings in terms of total travelled time and energy consumption.

The proposed solution approach consists of two main phases, namely a construction and an improvement phase. An initial feasible solution is generated within the construction phase utilizing the sequential insertion – based construction algorithm of Solomon. Geographical criteria are considered and the distance among bins constitutes the selection factor. One route is constructed at a time and the best un-routed bin is inserted to the best position at each iteration of the construction process. On return, the improvement method employs a metaheuristic Tabu search algorithm equipped with an "exchange" and a "relocate" edge-exchange neighborhood structures to drive the search process to improved solutions.

In the case of Piraeus city, the design process was particularly complex since there are multiple restrictions and limitations for consideration as well as issues to be resolved. Nevertheless, computational experiments demonstrated the competitiveness of the proposed solution approach. The re-designed routes in the pilot application gain reduced total distance travelled and improved energy efficiency. Future actions are planned, for a large scale implementation and the development of a unified efficient waste collection system.

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Keywords: waste collection; energy efficiency; vehicle routing; tabu search algorithm
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1. Introduction

Due to the ongoing urbanization of the Piraeus city, improving the efficiency of the waste collection system is imperative for a cost-effective operation with reduced traffic delays and pollutant emissions. In recent years, the Municipality of Piraeus has focused efforts on the management of the waste collection, which constitutes a major activity and includes complex processes such as vehicle routing and scheduling. The overall goal is to apply improved routes for the garbage collection service in an effort to gain significant savings in terms of total travelled time and energy consumption.

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The focus of this study is given on the proposed solution approach adopted by the Municipality of Piraeus to improve the current garbage collection system while the routing problem can be described as follows. Given a heterogeneous fleet of capacitated vehicles, the goal is to design a set of vehicle routes in order to satisfy the problem requirements. A set of bins are placed along the streets of the road network where the waste is gathered and must be collected by a fleet of vehicles whose capacity cannot be exceeded. Each vehicle can typically collect garbage from several waste bins before going to the waste disposal area to unload. Bins are unloaded every day and thus, waste is collected during workdays and weekends. Two different classes of routes are operated for each day i.e. the morning routes and the night routes. Each bin should be visited by only one vehicle and only once within the day. A vehicle after its return to the depot can be used again for a different route. The vehicles start and return to the depot while drivers work 8 hour shifts. However, in case of overtime work, extra pay is incurred. For the waste disposal area, there are predefined time windows during which the visit can take place. Figure 1 illustrates a solution to the routing problem for the garbage collection where the green spot indicates the depot location, the red spot the waste disposal area and black spots indicate the locations of the bins.

This study proposes a metaheuristic solution approach scheme to gain high quality solutions for the routing process of the garbage collection service, as it is an NP-hard computational optimization problem. The proposed solution algorithm utilizes a multi-restart solution framework. The suggested framework consists of a sequential insertion construction heuristic algorithm for building initial solutions, a Tabu Search algorithm (Gendreau et al., 1994) tuned for intensification search including several operators that are used to destruct and reconstruct solutions following a ruin-and-recreate principle with equal selection probability.

The remainder of this paper is organized as follows: section 2 provides a detailed description of the real-life problem while section 3 presents the proposed solution scheme. Computational experiments demonstrating the effectiveness of the proposed solution approach and the results gained by re-designed routes in the pilot application are presented in Section 4. Finally, in section 5 conclusions are drawn and future actions for a large scale implementation and the development of a unified efficient waste collection system are provided.

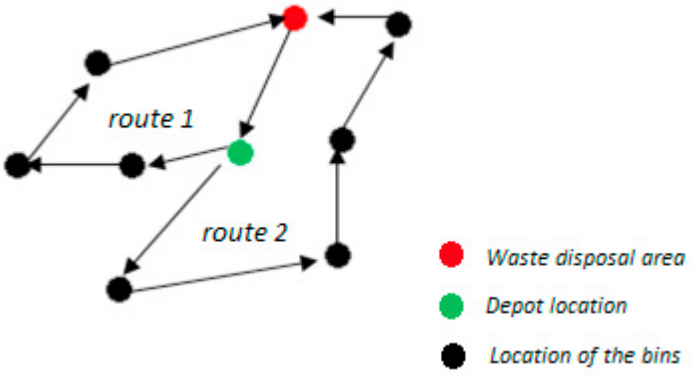

Figure 1 Depiction of a solution (2 routes)

2. Problem definition

Piraeus is a densely populated area, with 163688 residents. There are 1110 waste bins scattered throughout the city and the total waste generated per year is approximately between 75000 - 80000 tons. The city centre where most of the commercial units are clustered, faces an increased demand for waste collection services. This results in significant service inconsistencies, with increased daily traffic congestion, which constitutes a major problem for the area.

Waste collection is a social service offered to the residents and constitutes a major activity within the city operated by “Waste Management and Recycling Division” of the Municipality with no specialized private company participation. More specifically, the department of “Equipment and Vehicle Movement Management” is responsible