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Scheduling and routing models for food rescue and delivery operations

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ABSTRACT

Food rescue organizations are not-for-profit organizations that aid in alleviating hunger, by rescuing the surplus food from different food providers and re-distributing to welfare agencies supporting different forms of food relief. In this study, we present a scheduling and routing model that aims at simultaneously selecting a visit combination for each food provider and welfare agency, and designing routes to meet their required service levels minimizing the total transportation cost, while satisfying certain operational constraints. This problem is driven by food relief operations in Sydney. Our specific goals are to develop an integrated linear programming model and to propose a Tabu Search based heuristic solution approach for this scheduling and routing problem. We also implement the algorithm in a realistic food rescue and delivery network in Sydney. We test our heuristic algorithm on instances taken from literature and on small instances generated similar to that of Cordeau's benchmark instances and validate our solution approach against the optimal solutions obtained through the exact method before implementing it on food rescue and delivery network. Computational experiments indicate that the proposed method outperforms existing heuristics and is able to solve the real-world scenarios using significantly fewer resources than are employed in practice.

1. Introduction

Although, most of the industrialized and developed countries produce enough food to feed themselves and the rest of the world, millions of people live with very low food security. More than one third of the food produced is discarded from the manufacturing and the retail sector into landfill. Most of the food they throw away is avoidable and could have been consumed if it had been managed better. This hunger and food waste problem is being confronted by an ever-growing number of food rescue organizations (Foodbank, Second Harvest, Food Rescue, OzHarvest, Secondbite, City Harvest, Food Shuttle, etc.) which collect surplus food from different food providers and redistribute it to welfare agencies supporting various forms of food relief. Foodbanks are not-for-profit organizations which act as a pantry to the charities and community groups that feed the hungry. They rescue food products, including perishable goods, incorrectly labelled items, etc., from different local sources such as farmers, manufacturers and retailers. These food products are then stored in warehouses, sorted, packed and sometimes processed before being delivered to welfare agencies or to specific delivery points, accounting for the perishability of the products and the requests of agencies. In essence, they function as aggregators and distributors of surplus food rescued from various sources. There are many other food rescue organizations that collect food from these foodbanks and different food providers, including groceries, supermarkets, cafes, farmers, wholesalers, small vendors, restaurants, etc., and directly deliver at no charge to agencies providing assistance to vulnerable men, women and children. Due to the perishability of food products collected, they are not stored in warehouses, but are instead delivered on the same day itself. For these food banks and local food rescue organisations perishability of products is a major concern. Further, many research papers reported about the perishability issues in food rescue organisations [1,2,12,17]. In the

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current paper, we focus on food rescue operations, delivering food which in great part is ready for consumption, e.g., sandwiches, cooked meals donated by restaurants, dairy products with a short expiration date, etc. Thus perishability of the food is an important aspect that needs to be considered.

Generally, the rescued food products are categorized into perishable and long life products. Perishable products have a short lead time (a day) and are delivered on the same day they are rescued without storing in the warehouse. The leftover long-life products are stored in the warehouse for future use, but the left-over perishable products are considered as waste. Hence, it is critical to maximize the distribution of perishable products to avoid any wastage. They operate trucks that visit food providers and agencies daily. The trucks start from a depot, collect food from providers, and deliver it to agencies before returning to the depot. The optimal schedule and sequence of visits are determined based on the location of food providers and agencies, the quantity of food rescued and the demand of agencies.

The current study focuses on food rescue and delivery operations of OzHarvest, one of the largest and first perishable food rescue organization in Sydney. A detailed explanation on food rescue and delivery operations can be found in Nair et al. (2016) [1,2]. The network consists of around 800 food providers and more than 400 welfare agencies distributed over an area of 12,000 square kilometres. OzHarvest operates 13 truck routes, each visiting 10 to 20 food providers and 10 to 15 agencies daily. The trucks start from the depot, collect surplus food from the food providers, deliver it to the agencies, depending on their delivery demand and return to the depot at the end of their journey. Each agency has a request (demand) which is considered as a function of the type of food assistance they provide (breakfast program, community kitchens, food parcels, etc.), the size of the agency (number of people they support), etc. The food rescue organisations make collections at the food providers without any prior knowledge about the quantity and type of food available. The average supply of these food providers can be estimated from the historical data using appropriate forecasting techniques [1]. The surplus food available (supply) at a food provider is considered as a function of their type (grocery, supermarket, restaurant etc.) and size, and the day of routing. The delivery and pickup customers are visited on multiple days during the planning period as per their request. The planning period is considered as one week. The food providers require service multiple times a week depending on their frequency of donation. While some donate once a week, some donate multiple times a week and it depends on the type and size of food providers. The welfare agencies require service once or multiple times a week depending on the type of food relief they provide and their schedule of visit is flexible. Food collected from the food providers can be delivered to any welfare agency and their delivery demand can be met using the surplus food collected from one or more food providers. In fact, there is no pickup and delivery pairing constraint. Hence, the food rescue and delivery problem can be formulated as a Periodic Unpaired Pickup and Delivery Vehicle Routing Problem (PU-PDVRP) [2], a variant of the well-known VRP, where, food providers are the pickup customers and welfare agencies are the delivery customers. An example of food rescue and delivery operation (planning period 3 days) is provided in Fig. 1. The frequency of visits of customers 3, 5, 6 and 7 during the planning period is 1, customers 4, 8 and 9 is 2 and customers 1, 2 and 10 is 3.

The food rescue and delivery problem formulated as a PU-PDVRP, is a non-trivial extension of the classical VRP, which deserved a tailored algorithmic approach for its feasible and effective solution. Therefore, the heuristic and meta-heuristic approaches that have been used previously to solve other variants of VRP were not applicable for PU-PDVRP. This motivated us to propose a well-known Tabu Search based heuristic approach for this new variant. Tabu Search is a meta-heuristic algorithm proposed by Glover (1986) [3] which is known to provide good and potentially near-optimal solutions to difficult combinatorial problems and has been applied by many researchers to solve VRPs. Tabu Search explores intelligently a wider space of the possible outcomes and prevent the solution from getting trapped in local optima.

The contribution of this paper is towards developing models that address the major concerns of the food rescue and delivery problem. Food rescue and delivery VRP is a very complex problem that includes challenging aspects like, uncertainty in donations and donors, cost-effective scheduling of pickup and delivery nodes, cost-effective routing, limited transport resources, perishability of the rescued food, lack of storage space, equitable distribution of rescued food, etc. We believe that, it is necessary to divide this highly complex problem into sub-problems and identify feasible and efficient solution methods for each sub-problems before attempting to solve and implement it. As initial steps of a greater attempt of solving this problem, we proposed forecasting models [1] to handle uncertainty in donation of different food products, formulated scheduling and routing model

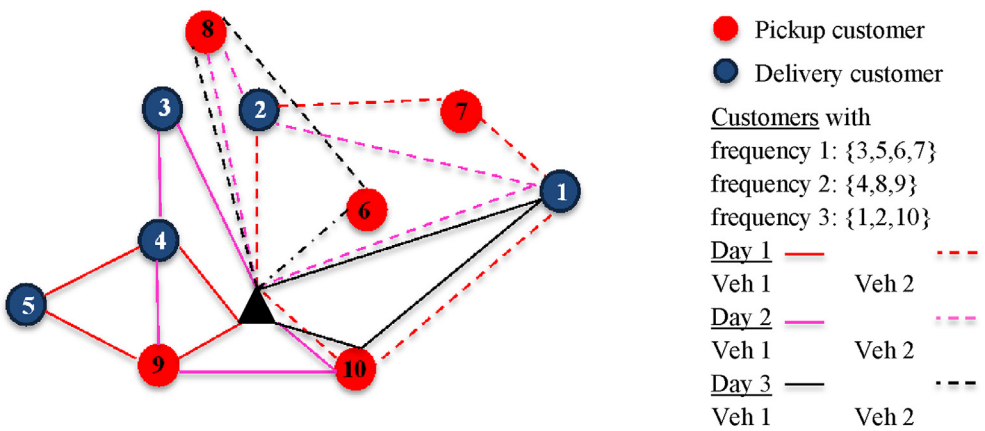

Fig. 1. Scheduling and routing problem using 2 vehicles and planning 3 days long period.

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