

# Solving Node Edge Arc Routing Problems in the Distribution of Media Products

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## Abstract

There is a strong pressure on economy in the distribution of media products. Two important remedies are more efficient carrier routes and distribution of side products. Both call for effective and dynamic route design and revision processes. These processes are complex, time-consuming, and costly. The size of industrial carrier route planning instances may cause performance problems for VRP algorithms. In the VRP literature, the Capacitated Arc Routing Problem (CARP) is often advocated as an adequate model for applications such as newspaper delivery and garbage collection. We argue that a better model is the Node Edge Arc Routing Problem (NEARP). We describe how we have extended a VRP solver to enable modeling of the NEARP, and extended it with a framework for multi-level aggregation of demand. An aggregation heuristic that is based on the underlying road topology is presented. The resulting solver has been integrated in a commercial web based system for route management and tested by pilot users. We present experimental results on real-life data from newspaper distribution. Results on standard CARP and NEARP instances from the literature are given, including several new best known solutions.

## Introduction

Distributors of media products such as newspapers face serious challenges due to falling subscription numbers. They need to reduce distribution costs and increase revenue. In countries like Norway, manpower is costly and the major cost driver for distribution companies. Hence, cost optimized logistics is crucial. Revenues can be increased by utilizing the logistics network for distributing side products. Both remedies call for powerful and reactive route optimization and revision processes. These tasks are complex, time-consuming, and costly. With a few exceptions, they are performed manually today. Routing tools may offer huge savings. However, several projects have failed due to serious challenges regarding the quality and granularity of electronic road data, the efforts needed to acquire missing data, the need for accurate models for travel and service time, and, the performance of VRP algorithms for large size instances.

Media products, particularly newspapers, are perishable goods. The distribution logistics involve a time critical supply chain from the printing shop to customers, i.e., a subset of all households in an area for a subscription newspaper. Normally, there are two stages: distribution from the printing shop to transfer points, and carrier distribution from transit points to customers. In this paper, we focus on the “last mile” part of the supply chain, the carrier distribution from transfer points to households and other customers. For a survey on distribution and routing in the newspaper industry, see [1].

The basic, node based carrier route design and revision problem may be formulated as a distance constrained capacitated VRP (DVRP) [2], possibly with side constraints and additional cost components. Often, the cost function is rather complex. They must reflect union agreements that may be particular to the distribution company at hand. Often, total route duration is a reasonable approximation. The number of carrier routes for a given set of points is often an important cost criterion. In some cases, the number of routes is given, and route duration should be balanced. Routes

may be designed to be pedestrian, whereas others will be serviced by car. In contrast with pedestrian routes, driven routes are open, as the carrier will not need to return to the transfer point. Transfer points may be fixed for all routes, or, a number of points are given as alternatives to choose from. In the latter case, the model must be extended to a location routing problem. Also, there are more strategic decisions regarding the design of carrier distribution zones and transfer points.

Together with Distribution Innovation AS, a Norwegian vendor of a web-based distribution route management system, we have developed functionality for automated route construction and revision. A generic solver for rich VRPs has been extended and integrated with the route management system. Route design and revision jobs are set up and initiated through the web, also using map visualization. The resulting routing plans are returned after a user defined timeout or a period of no improvement. The prototype has been tested by several distribution companies, with promising results.

## **Problem Model and Resolution Algorithms**

We focus on the design of carrier routes with fixed transfer points. An instance may consist of thousands of deliveries, which presents a real challenge even for state-of-the-art VRP algorithms. In the VRP literature, the Arc Routing Problem [3], particularly the Capacitated Arc Routing Problem (CARP) [4], is often advocated as an adequate model for applications such as newspaper delivery. A CARP formulation will typically have a significantly lower number of required arcs than the number of delivery / pickup points as many points will belong to the same arc. In many cases, the CARP may be an adequate abstraction; a subset of links in the road network must really be serviced at their full length. However, the basic locations of service in media product distribution are points, namely the mailboxes. There may be very long road segments with only a single mailbox close to a segment end point. A better, generic model of such applications is the Node Edge Arc Routing Problem (NEARP) [5,6,7]. Here, service is required on a subset of nodes, edges, and arcs in a mixed graph.

Good planning results are dependent on high quality information on demand, travel times, and service times. To avoid costly manual acquisition, models have been developed. There are a number of important, detailed practical issues regarding road traversal that need to be taken into account for realistic carrier route planning. Examples are one way streets, turning restrictions, and possibilities for meandering. High quality, detailed GIS information and additional company specific input are required. Options and restrictions are also dependent on the type of traveler. Available electronic road networks may lack the necessary level of detail, particularly in dense urban areas.

Given a problem instance with a large number of deliveries, a corresponding reduced instance is created through aggregation. A first level aggregation is normally performed by the distribution companies; they will create so-called *modules* of household deliveries where a module will never be split among routes. Modules have an associated reference point. Typically, a module will contain 5-10 households, but many more in dense, urban areas with blocks of flat. This aggregation serves two purposes: *abstraction* of travel details (in blocks of flat etc.), and *problem reduction*. A second level aggregation is performed automatically through a heuristic procedure. The procedure aggregates and sequences all modules that belong to the same road link, or a sequence of consecutive road links that are not interrupted by an intersection. We refer to [8] for a discussion of this idea on an idealized VRP model. There are volume and service time thresholds for aggregation. The aggregate order will have an *arc/edge location* that stretches from the first to the last module, as well as an associated aggregate size

and service time. Whether the location is an arc or an edge depends on the travel possibilities for the road segments involved, and the type of traveler. Empirical results show that a typical aggregation factor in urban areas is between 5 and 10.

To accommodate NEARP instances, and facilitate resolution of instances with a large number of nodes, we have extended a solver for rich VRPs [9] with arc/edge locations, a general framework for multi-level aggregation, and the aggregation heuristic described above. The VRP solver utilizes a combination of Iterated Local Search and Variable Neighborhood search, with a large repertoire of local search operators and diversifiers. To cater for the extended model, only minor changes to the algorithms were necessary.

## Empirical Results

The aggregation heuristics and the NEARP solution method have been tested on real cases from pilot distribution companies. Preliminary results are highly promising, with savings of up to 30% on accumulated distribution time relative to manually generated route plans. The solution method also produces good results on standard CARP and NEARP instances, including several new best known solutions.

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