Dynamic vehicle routing problems: Three decades and counting

Since the late 70s, much research activity has taken place on the class of dynamic vehicle routing problems (DVRP), with the time period after year 2000 witnessing areal explosion in related papers. Our paper sheds more light into work in this area over more than 3 decades by developing a taxonomy of DVRP papers according to 11 criteria. These are (1) type of problem, (2) logistical context, (3) transportation mode, (4) objective function, (5) fleet size, (6) time constraints, (7) vehicle capacity constraints, (8) the ability to reject customers, (9) the nature of the dynamic element, (10) the nature of the stochasticity (if any), and (11) the solution method. We comment on technological vis-à-vis methodological advances for this class of problems and suggest directions for further research. The latter include alternative objective functions, vehicle speed as decision variable, more explicit linkages of methodology to technological advances and analysis of worst case or average case performance of heuristics.

The Electric Traveling Salesman Problem with Time Windows

To minimize greenhouse gas emissions, the logistic field has seen an increasing usage of electric vehicles. The resulting distribution planning problems present new computational challenges. We address a problem, called Electric Traveling Salesman Problem with Time Windows. We propose a mixed integer linear formulation that can solve 20-customer instances in short computing times and a Three-Phase Heuristic algorithm based on General Variable Neighborhood Search and Dynamic Programming. Computational results show that the heuristic algorithm can find the optimal solution in most small-size instances within a tenth of a second and achieves goods solutions in instances with up to 200 customers.
A Predictive Maintenance Model for Railway Tracks
For the modern railways, maintenance is critical for ensuring safety, train punctuality and overall capacity utilization. The cost of railway maintenance in Europe is high, on average between 30,000 – 100,000 Euro per km per year [1]. Aiming to reduce such maintenance expenditure, this paper presents a mathematical model based on Mixed Integer Programming (MIP) which is designed to optimize the predictive railway tamping activities for ballasted track for the time horizon up to four years. The objective function is setup to minimize the actual costs for the tamping machine (measured by time). Five technical and economic aspects are taken into account to schedule tamping: (1) track degradation of the standard deviation of the longitudinal level over time; (2) track geometrical alignment; (3) track quality thresholds based on the train speed limits; (4) the dependency of the track quality recovery on the track quality after tamping operation and (5) Tamping machine operation factors. A Danish railway track between Odense and Fredericia with 57.2 km of length is applied for a time period of two to four years in the proposed maintenance model. The total cost can be reduced with up to 50% comparing to the optimization of the number of tamping [2][3], which shows that the model has great potential to support railway tamping planning in practice.

A Heuristic for Locating Electric Vehicle Charging Stations for Trip Chains
We present the problem of locating a limited number of electric vehicle charging stations for a given set of trip chains, each of which consists of a series of linked short trips and is represented by a sequence of intervening stops along the trip chain. The objective of this problem is to maximize the number of trip chains that can be completed by the electric vehicle without running out of battery. A mixed-integer programming formulation as well as a heuristic for solving this problem will be presented.
Combining Speed and Routing Decisions in Maritime Transportation

We present recent results on the problem of combining ship speed and routing decisions. Speed is a key determinant of the economic and the environmental performance affecting variables such as trip duration, fuel costs, and air emissions, among others. It is seen that inputs such as fuel cost, ship charter costs and cargo inventory costs may impact both speed and routing decisions. We develop models that optimize speed for a spectrum of routing scenarios and we use a heuristic method to solve them. Some examples are presented so as to illustrate the various trade-offs that are involved.

Routing of Electric Vehicles: Case Study of City Distribution in Copenhagen

In Copenhagen, Denmark, the preliminary steps of introducing an Urban Consolidation Centre (UCC) in the perimeter of the city centre has been taken. By implementing a UCC, interests of customers and distributors, as well as improvement of the local urban environment are sought considered [1]. The UCC service aims to consolidate urban freight, as well as implement additional aspects such as off-peak delivery and utilisation of alternatively fuelled vehicles.

In the specific case of Copenhagen, a comprehensive traffic survey was conducted in May 2011. The aim of the survey was to estimate freight magnitude and the distribution of goods in the old city centre. Based on the survey, analysis of possible UCC locations was carried out using simulation.

Distribution from the UCC is assumed to be conducted with electric vehicles (EVs) as they are considered suitable for the overall aim. However, compared to conventional distribution vehicles they have a limited driving range and a limited freight capacity. In this work, an Electric Vehicle Routing Problem with Time Windows (EVRPTW) is addressed. The EVs are allowed to recharge at certain customers or replenishment stations in order to continue a tour. Furthermore, intelligent location of these recharging points is considered. The objective is to find a least cost plan for routing and recharging the vehicles so that each customer is serviced by exactly one vehicle within its time windows and the vehicle capacity and driving range constraints are satisfied. The EVRPTW is a new problem that only has received little attention in the literature; see for example [2] and [3]. The costs are compared to distribution conducted by conventional vehicles. A heuristic method is developed and tested on the data generated on the basis of real-life collected data.

References


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Routing of Electric Vehicles: City Distribution in Copenhagen

In this work, a Vehicle Routing Problem with Time Windows considering EV constraints of limited driving range and freight capacity is addressed (EVRPTW). The EVs are allowed to recharge at certain locations, and aspects of intelligent location of these recharging points are considered. The objective is to find the least cost plan for EV routing and compare this to conventional routing. A heuristic method is developed and tested on data based on real-life collected data on distribution vehicles in central Copenhagen, Denmark. The EVRPTW has so far received little attention in the literature.

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Locating replenishment stations for electric vehicles: Application to Danish traffic data

Environment-friendly electric vehicles have gained substantial attention in governments, industry and universities. The deployment of a network of recharging stations is essential given their limited travel range. This paper considers the problem of locating electronic replenishment stations for electric vehicles on a traffic network with flow-based demand. The objective is to optimize the network performance, for example to maximize the flow covered by a prefixed number of stations, or to minimize the number of stations needed to cover traffic flows. Two mixed integer linear programming formulations are proposed to model the problem. These models are tested on real-life traffic data collected in Denmark. Computational results are presented.

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A multilevel variable neighborhood search heuristic for a practical vehicle routing and driver scheduling problem

The world's second largest producer of pork, Danish Crown, also provides a fresh meat supply logistics system within Denmark. This is used by the majority of supermarkets in Denmark. This article addresses an integrated vehicle routing and driver scheduling problem arising at Danish Crown in their fresh meat supply logistics system. The problem consists of a 1-week planning horizon, heterogeneous vehicles, and drivers with predefined work regulations. These regulations include, among other things, predefined workdays, fixed starting time, maximum weekly working duration, and a break rule. The objective is to minimize the total delivery cost that is a weighted sum of two kinds of delivery costs. A multilevel variable neighborhood search heuristic is proposed for the problem. In a preprocessing step, the problem size is reduced through an aggregation procedure. Thereafter, the aggregated weekly planning problem is decomposed into daily planning problems, each of which is solved by a variable neighborhood search. Finally, the solution of the aggregated problem is expanded to that of the original problem. The method is implemented and tested on real-life data consisting of
up to 2,000 orders per week. Computational results show that the aggregation procedure and the decomposition strategy are very effective in solving this large scale problem, and our solutions are superior to the industrial solutions given the constraints considered in this work.

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Rich Vehicle Routing Problems and Applications
The Vehicle Routing Problem (VRP) is one of the most important and challenging optimization problems in the field of Operations Research. It was introduced by Dantzig and Ramser (1959) and defined as the problem of designing the optimal set of routes for a fleet of vehicles in order to serve a given set of customers. The VRP is a computationally hard combinatorial problem and has been intensively studied by numerous researchers in the last fifty years. Due to the significant economic benefit that can be achieved by optimizing the routing problems in practice, more and more attention has been given to various extensions of the VRP that arise in real life. These extensions are often called Rich Vehicle Routing Problems (RVRPs). In contrast to the research of classical VRP that focuses on the idealized models with unrealistic assumptions, the research of RVRPs considers those complicated constraints encountered in the real-life planning and provides solutions that are executable in practice. In this thesis, we investigated the models and algorithms of three practical vehicle routing problems. Each of them involves special practical issues that are only considered in very few papers. Our study of these problems was motivated by our cooperation with industrial companies, particularly Transvision A/S and its client distributors, and Danish Crown. The models and methods proposed in the thesis are general and can be applied to practical routing problems arising in many other distribution companies as well. We first consider a vehicle routing problem with cross-docking options, in which products are picked up from suppliers by vehicles, consolidated at the depot and immediately delivered to customers by the same set of vehicles. It is more complex than the traditional vehicle routing problems in the sense that consolidation decisions have to be made at the depot and these decisions interact with the planning of pickup and delivery routes. We presented a mathematical model and proposed a Tabu Search based heuristic to solve it. It is shown that the approach can produce near-optimal solutions within very short computational time on real-life data involving up to 200 pairs of suppliers and customers. The second problem we consider is a dynamic vehicle routing problem with multiple objectives over a planning horizon that consists of multiple periods. In this problem, customer orders are revealed incrementally over the planning horizon. The delivery plan must be made and executed in every period without knowing the future orders. We modeled the problem as a mixed integer linear program and solved it by means of a three-phase heuristic that works over a rolling planning horizon. The method improves the company’s solution in terms of all the objectives, including the travel time, customer waiting and daily workload balances, under the given constraints considered in the work. Finally, we address an integrated vehicle routing and driver scheduling problem, in which a large number of practical constraints are considered, such as the multi-period horizon, the time windows for the delivery, the heterogeneous vehicles, the drivers’ predefined working regulations, the driving rule etc. The problem is formulated as a mixed integer linear program and treated by a multilevel variable neighborhood search algorithm. The method is implemented and tested on real-life data involving up to 2000 orders. It is shown that the method is able to provide solutions of good quality within reasonable running time.
The dynamic multi-period vehicle routing problem

This paper considers the Dynamic Multi-Period Vehicle Routing Problem which deals with the distribution of orders from a depot to a set of customers over a multi-period time horizon. Customer orders and their feasible service periods are dynamically revealed over time. The objectives are to minimize total travel costs and customer waiting, and to balance the daily workload over the planning horizon. This problem originates from a large distributor operating in Sweden. It is modeled as a mixed integer linear program, and solved by means of a three-phase heuristic that works over a rolling planning horizon. The multi-objective aspect of the problem is handled through a scalar technique approach. Computational results show that the proposed approach can yield high quality solutions within reasonable running times.

A multi-level variable neighborhood search heuristic for a practical vehicle routing and driver scheduling problem

This paper addresses an integrated vehicle routing and driver scheduling problem arising at the largest fresh meat producer in Denmark. The problem consists of a one-week planning horizon, heterogeneous vehicles, and drivers with predefined work regulations. These regulations include, among other things, predefined workdays, fixed starting time, maximum weekly working duration, break rule. The objective is to minimize the total delivery cost. The real-life case study is first introduced and modeled as a mixed integer linear program. A multilevel variable neighborhood search heuristic is
then proposed for the problem. At the first level, the problem size is reduced through an aggregation procedure. At the second level, the aggregated weekly planning problem is decomposed into daily planning problems, each of which is solved by a variable neighborhood search. At the last level, the solution of the aggregated problem is expanded to that of the original problem. The method is implemented and tested on real-life data consisting of up to 2000 orders per week. Computational results show that the aggregation procedure and the decomposition strategy are very effective in solving this large scale problem, and our solutions are superior to the industrial solutions given the constraints considered in this work.

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**A variable neighborhood search for a practical food distribution problem**

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**Dynamic multi-period vehicle routing problem**

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**The Dynamic Multi-Period Vehicle Routing Problem**
This paper considers the Dynamic Multi-Period Vehicle Routing Problem which deals with the distribution of orders from a depot to a set of customers over a multi-period time horizon. Customer orders and their feasible service periods are dynamically revealed over time. The objectives are to minimize total travel costs and customer waiting, and to balance the daily workload over the planning horizon. This problem originates from a large distributor operating in Sweden. It is modeled as a mixed integer linear program, and solved by means of a three-phase heuristic that works over a rolling planning horizon. The multi-objective aspect of the problem is handled through a scalar technique approach. Computational results show that our solutions improve upon those of the Swedish distributor.
Vehicle routing with cross-docking

Over the past decade, cross-docking has emerged as an important material handling technology in transportation. A variation of the well-known Vehicle Routing Problem (VRP), the VRP with Cross-Docking (VRPCD) arises in a number of logistics planning contexts. This paper addresses the VRPCD, where a set of homogeneous vehicles are used to transport orders from the suppliers to the corresponding customers via a cross-dock. The orders can be consolidated at the cross-dock but cannot be stored for very long because the cross-dock does not have long-term inventory-holding capabilities. The objective of the VRPCD is to minimize the total travel time while respecting time window constraints at the nodes and a time horizon for the whole transportation operation. In this paper, a mixed integer programming formulation for the VRPCD is proposed. A tabu search heuristic is embedded within an adaptive memory procedure to solve the problem. The proposed algorithm is implemented and tested on data sets provided by the Danish consultancy Transvision, and involving up to 200 pairs of nodes. Experimental results show that this algorithm can produce high-quality solutions (less than 5% away from optimal solution values) within very short computational time.