Program:

Workshop on OR in waste management

December 9, 2021

Below you find the information about the online platform, the presentations, and the program. We wish everyone a productive and enjoyable workshop.

Sanne Wøhlk and Remy Spliet

Online platform: Zoom

We will use Zoom as our platform for the online workshop. You can download the app using this link: https://zoom.us/download. To participate in the workshop, a specific Zoom link is required which will be send to registered participants. Some instructions on using Zoom will be given at the start of the workshop, during the 'Welcome'.

Presentations

With the exception of the invited lecture by Daniele Vigo, the presentations take place in three sessions. For each presentation we have scheduled 20 minutes, which consists of 15 minutes for the talk, and 5 minutes of slack for questions and setting up the next presentation. The workshop organizers will act as chairs to coordinate each session.

Program

The program can be found in the table below. The contents of Session 1, 2 and 3 are provided on the following pages. This includes the title, authors, and abstract of each presentation, with corresponding times.

Central European Time	Event
9:00 – 9:10	Welcome
9:10 – 10:30	Session 1
10:30 – 11:00	Break
11:00 – 12:00	Session 2
12:00 – 13:00	Break
13:00 – 14:00	**Invited lecture by Daniele Vigo**, on his experiences with solving practical waste management problems
14:00 – 14:30	Break
14:30 – 15:30	Session 3
15:30 – 15:40	Close

Session 1, 9:10 – 10:30 (CET)

9:10 – 9:30 **A rich solid-waste collection problem with intermediate facilities and consistent routes**

Christina Hess, Alina G. Dragomir and Karl F. Dörner

In this work we deal with a real-world inspired routing problem arising in the field of solid waste collection. The problem is concerned with the collection of plastic waste in an urban area with several thousand bins. Scattered sensors are used to measure fill levels in order to obtain information about the demand. With a fleet of vehicles located at multiple depots, a weekly routing plan shall be established. Additionally, trips to the incinerators have to be scheduled mid-route and at the end of the route. We model our problem as a multi-depot periodic vehicle routing problem with intermediate facilities (MDPVRPIF). The goal is to create stable routes that minimize travel time while allowing overflows within a certain range. As drivers become familiar with visited locations, their work efficiency increases. Therefore, routes need to be consistent and realizable with only minor adjustments even if the amount of waste fluctuates. For now, we define the problem, discuss different model assumptions, and present preliminary results of small instances solved by an adaptive large neighborhood search (ALNS) algorithm. In the future, we plan on using more advanced forecasting methods and adapting the ALNS to solve the stochastic version of the problem.

9:30 – 9:50 **Modeling and solving the waste collection routing problem by a fleet of hybrid vehicles**

Sajjad Hedayati, Mostafa Setak, Tom Van Woensel and Emrah Demir

In this research, we study the waste collection routing problem in which a fleet of hybrid vehicles collects solid waste from transfer points located at distinct subregions in an urban area. The aim is to define feasible optimal tours with minimum emission for the fleet by which each type of waste is collected by a specific vehicle from transfer points is associated with multiple time windows. They start their trips from a central depot but deliver collected waste to different destinations. Moreover, a hybrid vehicle needs to be charged during its route once by charging stations scattered in the geographical area. We formalize this problem as a mixed-integer program and present some valid inequalities for improving the processing time.

9:50 – 10:10 **Sensor placement in a single-period waste collection problem**

Ymro Hoogendoorn, Remy Spliet and Daniele Vigo

A recent development in waste collection is the placement of sensors to reduce uncertainty. However, as placing sensors require both installation and upkeep costs, we want to make an informed decision to place sensors. In addition, sensors are not perfectly accurate and we have to choose between cheaper sensors that give imprecise readings, or more expensive sensors that give precise readings. Given the readings of the placed sensors, the single-period waste collection problem reduces to a vehicle routing problem with stochastic demands (VRPSD). We allow for correlated demand. The VRPSD can be solved exactly by means of an integer L-shaped method. However, to evaluate different sensor placements, the expected costs of a single sensor placement needs to be calculated, which is equivalent to computing the expected cost of many different optimal VRPSD solutions. In this research, we derive theoretical properties of this placement problem, and devise different methods to approximate or upper bound the expected costs of a sensor placement. These expected costs are then used to infer strategies for sensor placements using instances found in waste collection practice.

10:10 – 10:30 **On the extension of a capacitated multi-vehicle covering tour problem to accommodate intermediate disposal facilities and a heterogenous vehicle fleet**

Vera Fischer

Door-to-door waste collection comes with a high fuel consumption, emissions and noise. These can be confronted by locating collection sites throughout the municipality such that residents bring their waste to their most preferred (e.g., closest) location. We formulate this problem as a capacitated multi-vehicle covering tour problem, in which routes of minimum total length are designed such that the nodes to cover (residents) lie within a given distance of a node visited by a vehicle (collection sites). Despite the reduction in the number of stops, this strategy does not allow to use smaller collection vehicles (which are more sustainable) because the disposal facility is typically far away. This can be addressed by introducing intermediate disposal facilities within the municipality. We are interested in extending the problem to accommodate intermediate disposal facilities and a heterogenous vehicle fleet.

Session 2, 11:00 – 12:00 (CET)

11:00 – 11:20 **On the effect of using sensors and dynamic forecasts in inventory-routing problems**

Remy Spliet, Maximiliano Cubillos and Sanne Wøhlk

We study an inventory-routing problem with stochastic demand, in which knowledge of the demands of customers can be updated by the use of sensor information, and used to plan delivery decisions in a given planning period. We consider the case in which a limited number of sensors can be placed, and investigate what simple rules can best be applied to decide on their allocation. To evaluate these simple sensor allocation rules, we propose a Variable Neighborhood Search algorithm for an inventory routing problem in a rolling horizon framework to solve the problem which uses both sensor and historical data to update demand forecasts. We perform extensive computational experiments in which we generate random instances and consider different demand generation scenarios to test different sensor allocation rules. Results show that simple allocation rules, such as placing sensors at customers with high demand or far from the depot, can significantly reduce the total cost, particularly if combined with dynamic forecast information.

11:20 – 11:40 **Throwing out food before expiration and still reducing food waste: online vs. offline retail**

Sena Eruguz, Jorrit Barto, Remy Spliet and Sanne Wøhlk

When you order food online, say at an online supermarket, you typically don't tell the retailer when you are going to consume the food. In response, retailers make reasonably sure that the ordered food can be consumed before expiration. For example, the retailer might only deliver food which is valid for at least one more week. Food that expires sooner is unsalable and wasted. In contrast, when buying food offline you pick your own products and have full information. Hence, you can still buy food that expires tomorrow, if you intend to consume it today. Therefore, offline stores only throw out food after expiration. Although it might seem that online retail is more wasteful, because food is thrown out before expiration, we argue that in fact it is less wasteful. Online retail benefits from the pooling effect and the ability to enforce FIFO inventory depletion. In our experiments, the advantages of online retail more than make up for the food that is wasted by throwing it out before expiration.

11:40 – 12:00 **Vehicular Technologies in Recyclable Waste Collection: How Do They Affect Service?**

Hani Zbib and Gilbert Laporte

Within the context of circular economies, recycling has gained a lot of traction, which consequently resulted in waste collection becoming more complex due to the many recycling-related technological features and configurations available on waste collection vehicles. These technological features can highly affect the efficiency of the recyclable waste collection service, mainly the collection time and the design of collection routes. We present a decision support tool for municipal entities responsible for recyclable waste collection from households to aid in their fleet mix decisions given the catalogue offering of a recycling trucks manufacturer. To that end, we analyse the catalogue offerings of several trucks manufacturers and identify the technological features of collection vehicles that affect the recyclable waste collection service, and show how these features and their different configurations can be modelled.

Session 3, 14:30 – 15:30 (CET)

14:30 – 14:50 **The WSmart Route Research Project**

Tânia Ramos

The WSmart Route project (Waste Collection based on a Real Time Route Planning System) explored a new paradigm based on smart waste management, where real-time information plays a central role in changing the way operations are managed today. Recent advances in ICT make it possible to access information in real time through the use of sensors located inside the containers. However, access to the information collected by these sensors is not sufficient to increase efficiency in the waste collection operation by itself, making it essential to optimize the collection routes according to that information. This project aimed to compare different waste bin monitoring approaches (sensors versus visual observations by the drivers), develop new mathematical models and solution methods for the definition of optimal routes given the information sent by the technology, and assess the benefits comparing the "as-is" to the "to-be" situation in a real case study.

14:50 – 15:10 **Coordinating supply chains for sustainability – creating incentives that work**

Philip A. Tominac and Victor M. Zavala

Supply chains (SCs) are complex, interconnected networks comprising stakeholders with different capabilities and goals. While globalization has created cost efficiencies, its objectives tend to oppose demands for increased sustainability, creating complex challenges in SC management. Recent work has shown that coordination (a market management strategy used in electricity grids) can be adapted to multiproduct SCs. Coordination provides useful theoretical guarantees related to economic fairness (profit allocations and revenue adequacy) that ensure SC stakeholders will not be allocated losses. Moreover, we are able to identify stakeholders (suppliers, consumers, transportation providers, product processing providers) as agents driving the behavior of prices. In this presentation, I will show how we have adapted coordination to multi-product supply chains and incorporated sustainability through the modification of our framework to include externalities and emissions in terms of environmental policy decisions (e.g., carbon taxes). This coordination approach builds on an economic interpretation of sustainability, revealing the inherent value of environmental impacts in the context of achieving better supply chain outcomes. Coordination allows us to approach sustainability through the concept of prices and incentives, providing a foundational framework to broaden the scope of SC design to include sustainability and to understand sustainability through SC economics. We demonstrate this approach with a case study using a waste management case study in the city of Milwaukee, WI.

15:10 – 15:30 **Is it beneficial to collect household waste based on requests?**

Sanne Wøhlk

This question was posed by the municipality of Glostrup, a suburb of Copenhagen. Traditionally in Denmark, waste is collected with fixed intervals of one to eight weeks; depending on the type of waste. However, the responsible waste collection company observed that many bins are not full when emptied. This motivated a pilot study where some citizens could, instead, request when to have their bins emptied. This formed the data foundation of a large simulation study, involving requests and planning of collection routes for the whole municipality, where the cost and service levels of different systems based on requests are compared to the original system.