Case descriptions

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1 Returpack

Returpack Swedish AB is responsible for the return system of metal cans and plastic bottles in Sweden. “Returpack is receiving more than 1.5 billion cans and PET bottles every year, making Sweden a leading country in recycling PET and metal cans.”

Returpack has over 10 000 clients (stores, restaurants, etc.) submitting empties. It pays about 1.6 million each year in deposit (“pant”).

Approximately 3,200 customers have pantautomata. There Returpack fetches the empties in special cars, or they are sent to a wholesaler or beverage supplier. Roughly 7,000 restaurants etc. are manual customers. They submit packaging in bags to wholesalers, or beverage suppliers. Returpack is also working with major festivals and ski facilities.

One expects volume increases, and would also like to reduce the environmental impact, primarily due to reduced mileage. The company’s goal is to recycle 90 % of cans and PET (today it is about 88 %) and lower the cost of the deposit system.

The recycling system is intended to be cost neutral, meaning that the deposit paid should cover the costs, and the costs should be distributed to the various stakeholders so that everyone gets coverage the cost, but no one makes a profit.

It is a complex system that Returpack has to deal with. The flow of goods is as follows. It starts with the consumer submitting empty cans and bottles in stores. They are stored there for a short time, packaged and shipped to a wholesaler. There is additional storage, and then the goods is sent on to Returpack. A certain flow also goes from the store to the brewery, which then deliver to Returpack.

At Returpack cans and PET bottles are collected from shops and restaurants all over Sweden. The cans and bottles are sorted, counted and baled. Each year, about 14,000 tonnes aluminum and 19,000 tonnes of PET materials are produced. The recycled material is sent on in the cycle to other companies where it is used in production of new cans and bottles.

Returpack thus sends the goods to raw materials manufacturers, that recycle the material. Then the raw materials producers send material to packaging manufacturers that makes the new packaging. These packages are delivered to breweries, who send them (with drinks in) to wholesalers and/or directly to stores. There they are purchased by consumers, who drink the the contents of them.

There is also another side, namely the “monetary” flow, i.e. the financial compensation. The deposit follows the package throughout the flow. Breweries pays deposit to Returpack for all cans and bottles they supply to the market. Merchants pay a deposit to importers and breweries. The shop pays deposit to the wholesalera and the breweries. Consumers pay deposit to the store when purchasing beverages.

The shop then pays the deposit to the consumer, when he/she returns the empties. When the empties go through the vending apparatus, a file is made and weekly collected by the vending machine supplier to be sent on to Returpack. Returpack pays the deposit to the stores. Breweries and importers pay for administration to Returpack, and Returpack pay compensation for the management of stores.

If consumers do not recycle the empty, but instead throw it in the garbage, the deposit stays at Returpack. The difference is called “pantnetto”.

Returpack is considering replacing the wholesalers’ role in the flow with warehouses of their own. Moreover, one is considering not to carry the empties in cartons, but in plastic bags, which can be retrieved with something like a garbage truck. This makes transportation more efficient and cheaper.

This material is taken from Björklund och Ekdahl (2010), and from the homepage of Returpack.

2 Plug-in hybrid electric vehicle

We consider a rechargeable hybrid electric vehicle, “plug-in hybrid electric vehicle ”, PHEV. (“laddhybrid”). It is a car with both an electric motor and gasoline engine, with the possibility to switch between different modes. (The term electric machine is better than electric motor, since the battery can be recharged during braking.) It is possible to charge the battery via a power outlet. Full charging of the battery then takes several hours, and is done for example at night, when the car is stationary in the garage. You can also charge the battery at special charging stations, and then the charging is faster. It takes, however, still significantly longer than filling of gasoline, so one does not like to do this while waiting. We consider a one-day excursions, with the charge before the trip, and no external charging under the journey.

There are a few different modes for the hybrid engine:

1. Only electricity.
2. Only gasoline.
3. Mixed, retains its power.
4. Mixed, the charge decreases in specific pace.

Functionality 1 can be used until the battery is empty, i.e. until the charge falls below a certain lower limit. Operation 2 can always be used, but is best avoided. Operation 3 means that both electricity and gasoline used. The battery is charged automatically when braking, and the battery charge is maintained at all times within fairly tight given limits. This option uses just as much gasoline as needed to keep the charge up. Operation 4 involves a different mix of electricity and gasoline. The battery charge decreases, but not as fast as in Operation 1. It takes gasoline, but not as much as in Operation 3.

As one can easily refill the gasoline, we do not consider the possibility that the gasoline runs out. It is instead important to use the battery charge as “optimally” as possible. The goal is that the battery will be just enough for the journey, and will be finished when you arrive. If the charging ends prematurely, you must use much gasoline for the rest of the journey. If you do not use the whole battery charge completely, it means that you have used too much gasoline. A basic assumption is that gasoline is more “expensive” than electricity, especially with respect to the environment.

Electric power is better than petrol when driving at low speed and if there are many starts and stops. Typical examples are urban transport, especially if there are queues that force the car to be completely stationary at times.

To optimize the function during a trip, it is necessary to know how the journey will go. We therefore assume that we know the starting point and end point, and knows exactly which path the car will take between these points.

We divide the distance to be run in small parts, where each part may be considered to have constant properties. The parts may have different lengths. A longer stretch with 70 km/h speed limit, in principle without traffic obstacles and hills, can be seen as a homogeneous part. In cities, however, a finer division motivated.

Obviously, this discretisation means an approximation, i.e. small errors are introduced in the model. We will therefore not get the exact optimal solution, but only a solution quite close to optimum (near optimal). The problem is so difficult it must be seen on impossible to find exactly the optimum. The error caused by the discretization depends on the size of the parts dividing the road. A few sections give a smaller model with larger errors, while a large number of smaller parts gives a better solution, but a much larger model, which takes longer to solve. The choice of discretization point must be a balance of these two effects. (An unsolvable model is not useful.)

Suppose now that we have a given discretization so that our path consists of a large number of homogeneous parts. Every part has certain properties, slope, the expected average speed, amount disturbing traffic, and probabilities of other disorders. These properties may be converted to different effects in the different modes of propulsion.

Thus, one can calculate how much gasoline is consumed during the different modes of operation for each section of the road, and also how much the charging of the battery is spent. We do not change the operation mode within a road segment, but only in points between the parts.

A dynamic solution method feels most natural. Suppose you have decided how much charge one should have left in the battery after the first part. Then it is easy to determine how the first part should be run. This can be repeated iteratively.

This leads to a solution method of dynamic programming type. We are building a acyclic graph in levels where each node corresponds a particular location on the road (between two parts) and a certain battery charge (discreticized to certain levels).

To run a particular road segment with a particular operation means moving forward a step, but also a change of the the battery charge. In addition, there is a certain cost.

We introduce *all* these arcs, which models all the possibilities to get from the start point to the end point. We then find the cheapest path from the starting point to the end point. This path provides the solution.

The problem is described briefly in Fairley (2009).

3 Snow removal

An important activity in northern countries is snow removal and related activities such as road salting, sanding and uptake of sand in the spring. Here the public in principle always requires that it should be managed in a perfect way. Otherwise countless complaints ar incurred. The snow must be quickly and efficiently removed from the streets, bike paths, sidewalks, bus stops, public squares etc. First, it plowed aside, and later (if there is a lot of snow) moved to storage sites, where it is not in the way.

One interesting optimization problem is to determine how the vehicles should drive. It takes place in a graph, the traffic network, i.e. the streets, and the question is when and in what order the various road sections should to be tackled and by which vehicle. The vehicles that perform snow removal consumes a lot of fuel and gives quite large emissions of exhaust gases. If they run back and forth unnecessarily much, a significant negative environmental impact is obtained.

Here one can see similarities with postman problems, since it has a number of streets/arcs that all should be cleared. The problem is however more complicated, because most streets are plowed not just once, but two or three times, first in the middle, then right side and then left side. One must also do additional clearing of turning spaces and intersections, and it can be done only after the the connecting streets have been cleared. It is not absolutely necessary that the same vehicle makes all these tasks on a particular street, but in practice it is usually so.

Other complicating factors is that you often have several different vehicles, which run at different speeds and can do different things. If we are to make detailed plans and also have requirements that some vehicles do not fit on the same street at the same time and that it takes more time to turn a vehicle around than to continue straight ahead, the model becomes more complex.

The problems are different depending on whether one is studying snow removal in urban or rural areas, and it if is during snowfall or after completion of snowfall. During a snowfall one must return to already cleared roads and repeat the clearing. Somewhat simplified, it is all about find good cycles for vehicles, which they can then drive repeatedly. Snow removal during a snowfall in rural treated in the PhD dissertation Razmara (2004).

Fortunately snowing always ends at some time. After finished snowfall each task only needs to be done once. When all tasks are done, you are finished. The objective function is often that everything should be ready after as short time as possible. One can also consider minimizing the distance driven without clearing or minimizing exhaust emissions.

Several aspects of these optimization problems are discussed in detail in the articles Perrier, Langevin, och Campbell (2006a), Perrier, Langevin, och Campbell (2006b), Perrier, Langevin, och Campbell (2007a), Perrier, Langevin, och Campbell (2007b). Snow removal in cities is covered in Perrier, Langevin, och Amaya (2008). In summary, one can say that there it is a complex optimization problem which can hardly be solved exactly to optimality. Therefore, various heuristics are of great interest.

Referenser

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