Problem Solving Competition - 2010

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Contents

DISCLAIMER: *The problem presented here exemplifies one of several opportunities for Operations Research application in the Railway industry. We have simplified a real-life problem for this competition. More general problems and related literature is available on the competition web-site under the section Related Literature. Best of luck for the competition.*

Locating Locomotive Refueling Stations

1 Problem definition

Fuel expenses are a significant part of any railroad's operating costs. Fuel delivery costs differ from location to location because of the differences in distribution, marketing costs and other factors; e.g., as of August 1, 2006, one gallon of diesel costs one of the Class-I railroad company $2.2057 in Atlanta, GA, but $2.2823 at Augusta, GA. A railroad faces the problem of identifying a cost effective plan to fuel the locomotives that power its trains.

A train schedule defines, among several other attributes, the sequence of yards in which a train stops on its route from origin to destination. It also defines its train-starts or days of operation. If a train operates 3 days per week, say Monday, Wednesday and Friday, then the train-starts for that train at its origination yard are Monday, Wednesday and Friday. This is usually represented by a string notation (M-W-F– OR YNYNYNN). The sequence of yards in which a train stops is identical on any train-start. Further, a train-start may run over one or more days, for example, a Monday train-start may run for two days, starting on Monday from its origin and arriving at its destination yard on Tuesday. For this competition it is assumed that all trains are started everyday (train start-MTWTFSS OR YYYYYYY) and that the schedule of each train repeats every week.

Trains are powered by locomotives, and although the number of locomotives might differ from train to train, for this competition it is assumed that each train requires exactly one locomotive and that all locomotives are identical. A locomotive plan assigns engines to train start sequences. This plan dictates the train-starts that each locomotive will power. The plan is setup in such a way that for each locomotive the sequence of train-starts repeats over one or more weeks constituting what is called a locomotive train assignment cycle. The duration of these cycles determine the *planning horizon*. For this competition we assume that this duration is the same for all locomotives and therefore the planning horizon under consideration corresponds to the duration of any locomotive train assignment cycle.

Locomotives consume fuel at a per mile rate and there is a limit to the maximum amount that can be dispensed into a locomotive determined by the locomotive tank-capacity. Locomotives can only be refueled at yards. For this competition it is assumed that there is only one source of fuel: fueling trucks. Fueling truck contracts are annual, and it is further assumed that currently there are no active contracts. Fueling trucks have a weekly operating cost and a fuel price per gallon that can change from yard to yard. Each truck has a capacity that determines the maximum amount of fuel that it can dispense in one day. A locomotive may be refueled at the train's origin or intermediate yards where the train stops; however, a locomotive may not be refueled at the train's destination yard. Assume instantaneous refueling time, and that a train incurs a fixed cost if it is refueled. Additionally, there is a restriction on the maximum number of times a train can stop to be refueled (excluding the origin).

The railroad needs to identify a fueling plan that minimizes total fuel-related expenses over the planning horizon. This includes truck operating costs as well as fuel purchasing costs. This plan must specify the number of trucks that should be contracted at each yard, and the quantity of fuel that must be dispensed into each locomotive at every yard on every train-start in the locomotive train assignment cycle. The plan must ensure that all locomotives have enough fuel to run all trains according to the schedule (i.e., no locomotive can run out of fuel on its route between yards).

2 Example

We now provide a simple example to illustrate the concepts described in the previous section. The problem is described in terms of tables that illustrate the format of some of the files used to describe the problem instance for this competition.

Consider a simple railroad network made of four yards: Y1,Y2, Y3 and Y4. There are tracks connecting directly Y1 with Y2, Y2 with Y3, and Y3 with Y4. Two trains (T1 and T2) run in this railroad everyday of the week. Assume that for T1 the sequence in which it stops at yards is [Y1, Y2, Y3, Y4]. The sequence in which T2 stops at yards is [Y4, Y2, Y1]. Observe that a train may not stop at every yard on its route. The train schedule for T1 and T2 is presented in Table 1. In this table a value of 1 for Day of Journey implies that the train arrives and departs the corresponding yard on the same day as the train's start-day; a value of 2 implies that the train arrives and departs the corresponding yard one day after the train's start-day, and so on.

Train	Yards	Sequence	Day of Journey	Station Type
T1	Y1	1	1	Origin
	Y2	2	1	Intermediate
	Y3	3	1	Intermediate
	Y4	4	1	Destination
T2	Y4	1	1	Origin
	Y2	2	1	Intermediate
	Y1	3	1	Destination

Table 1: Train Schedule - Train-starts defined by YYYYYYY

The distance between yards is symmetrical and can be found in the Table 2.

Yard1	Yard2	Distance (Miles)
Y1	Y2	106
Y2	Y3	146
Y2	Y4	162
Y3	Y4	16

Table 2: Distance between yards

There are two locomotives available to power trains: L1 and L2. Each train needs to be powered by exactly one locomotive. L1 and L2 take staggered turns everyday at pulling trains T1 and T2. The locomotive train assignment cycles for L1 and L2 are presented in Table 3. In Table 3 column Cycle Sequence determines the sequential order in which each locomotive is assigned to a train. Additionally, Horizon Day is used to denote the actual day within the planning horizon in which an event takes place; in this case it represents the day in which a locomotive powers a train. Observe that both L1 and L2 complete a locomotive train assignment cycle in exactly two weeks; therefore in this example we are looking at a 14 day planning horizon.

Each locomotive consumes 3.5 gallons of fuel per mile and a locomotives tank holds up to

LocoID	Train	Train Start Day	Week	Cycle Sequence	Horizon Day
L1	T1	MON	1	1	1
	T2	TUE	1	2	2
	T1	WED	1	3	3
	T2	THU	1	4	4
	T1	FRI	1	5	5
	T2	SAT	1	6	6
	T1	SUN	1	7	7
	T2	MON	2	8	8
	T1	TUE	2	9	9
	T2	WED	2	10	10
	T1	THU	2	11	11
	T2	FRI	2	12	12
	T1	SAT	2	13	13
	T2	SUN	2	14	14
L2	T2	MON	1	1	1
	T1	TUE	1	2	2
	T2	WED	1	3	3
	T1	THU	1	4	4
	T2	FRI	1	5	5
	T1	SAT	1	6	6
	T2	SUN	1	7	7
	T1	MON	2	8	8
	T2	TUE	2	9	9
	T1	WED	2	10	10
	T2	THU	2	11	11
	T1	FRI	2	12	12
	T2	SAT	2	13	13
	T1	SUN	2	14	14

Table 3: Locomotive train assignment cycle for L1 and L2

4500 gallons of fuel. Therefore, on a full tank a locomotive can run for approximately 1285.71 miles. Further, assume that a fueling truck can fuel up to 25000 gallons per day. The weekly operating costs per truck is $4000 and fuel costs per gallon at each yard are given in Table 4. The fixed refueling cost is $250. A train may not make more than 2 refueling stops (excluding the origin of the train).

Yard	Fuel price ($/gallon)
Y1	$3.25
Y2	$3.05
Y3	$3.15
Y4	$3.15

Table 4: Fueling costs

3 Feasible Solution

In this section we present a feasible solution to the specific problem instance described on the previous section. The solutions is provided in terms of tables to illustrate the format used for describing solutions in this competition. A solution has two important components:

1. Decisions on the number of trucks contracted for each yard.
2. Fueling plan for each locomotive train assignment cycle.

The solution we present in this section contracts one fueling truck at yard Y2. The decisions on the number of contracted trucks for each yard are described on Table 5.

The Fueling plan for each locomotive train assignment cycle is described in Table 6. In this table the first column marks the sequence of yards where the corresponding locomotive can be refueled. Column Horizon Day denotes the day in the planning horizon in which the this event takes place. Observe for example that for L1 the first visit to Y4 is associated with the second day of the planning horizon because it is assumed that any train, and therefore its locomotive, may not be refueled at its destination. Hence this entry for L1 is associated with train T2. In order to make this evident, we included column Station Type, from which it is clear that no refueling takes place at the train's destination. Finally column Stop Number is used to describe the sequential order of potential refueling stops for a locomotive.

Table 6 illustrates the cyclic nature of this problem. Observe that neither L1 nor L2 are refueled for the first sequence of the train assignment cycle (i.e., first row on the table) and this is still a feasible solution because both locomotives still have fuel remaining from the previous occurrence of the cycle. From this table it can be inferred that the fuel level associated with Stop Number 1 (first row) before departure is 377 and 2443 gallons in L1 and L2 respectively. Finally, observe that both L1 and L2 are always fueled in yard Y2.

The cost of this solution over the planning horizon (2 weeks) is \$90105.2. Fuel costs are \$80105.2, truck costs are \$8000 and the stop costs are \$2000.

Yards	Number of trucks
Y1	0
Y2	1
Y3	0
Y4	0

Table 5: Decisions on number of trucks for each yard in the solution

L1					L2				
Yard	Stop No.	Stn Type	Horizon Day	Gallons	Yard	Stop No.	Stn Type	Horizon Day	Gallons
Y1	1	Origin	1	0.00	Y4	1	Origin	1	0.00
Y2	2	Intermediate	1	1870.00	Y2	2	Intermediate	1	0.00
Y3	3	Intermediate	1	0.00	Y1	3	Origin	2	0.00
Y4	4	Origin	2	0.00	Y2	4	Intermediate	2	0.00
Y2	5	Intermediate	2	0.00	Y3	5	Intermediate	2	0.00
Y1	6	Origin	3	0.00	Y4	6	Origin	3	0.00
Y2	7	Intermediate	3	4500.00	Y2	7	Intermediate	3	4500.00
Y3	8	Intermediate	3	0.00	Y1	8	Origin	4	0.00
Y4	9	Origin	4	0.00	Y2	9	Intermediate	4	0.00
Y2	10	Intermediate	4	0.00	Y3	10	Intermediate	4	0.00
Y1	11	Origin	5	0.00	Y4	11	Origin	5	0.00
Y2	12	Intermediate	5	0.00	Y2	12	Intermediate	5	0.00
Y3	13	Intermediate	5	0.00	Y1	13	Origin	6	0.00
Y4	14	Origin	6	0.00	Y2	14	Intermediate	6	0.00
Y2	15	Intermediate	6	3010.00	Y3	15	Intermediate	6	0.00
Y1	16	Origin	7	0.00	Y4	16	Origin	7	0.00
Y2	17	Intermediate	7	0.00	Y2	17	Intermediate	7	0.00
Y3	18	Intermediate	7	0.00	Y1	18	Origin	8	0.00
Y4	19	Origin	8	0.00	Y2	19	Intermediate	8	4494.00
Y2	20	Intermediate	8	0.00	Y3	20	Intermediate	8	0.00
Y1	21	Origin	9	0.00	Y4	21	Origin	9	0.00
Y2	22	Intermediate	9	0.00	Y2	22	Intermediate	9	0.00
Y3	23	Intermediate	9	0.00	Y1	23	Origin	10	0.00
Y4	24	Origin	10	0.00	Y2	24	Intermediate	10	0.00
Y2	25	Intermediate	10	3752.00	Y3	25	Intermediate	10	0.00
Y1	26	Origin	11	0.00	Y4	26	Origin	11	0.00
Y2	27	Intermediate	11	0.00	Y2	27	Intermediate	11	386.00
Y3	28	Intermediate	11	0.00	Y1	28	Origin	12	0.00
Y4	29	Origin	12	0.00	Y2	29	Intermediate	12	0.00
Y2	30	Intermediate	12	0.00	Y3	30	Intermediate	12	0.00
Y1	31	Origin	13	0.00	Y4	31	Origin	13	0.00
Y2	32	Intermediate	13	0.00	Y2	32	Intermediate	13	3752.00
Y3	33	Intermediate	13	0.00	Y1	33	Origin	14	0.00
Y4	34	Origin	14	0.00	Y2	34	Intermediate	14	0.00
Y2	35	Intermediate	14	0.00	Y3	35	Intermediate	14	0.00

Table 6: Fueling plan for each locomotive train assignment cycle in the solution