Tutorial # 7: Decision Aid Methodology
29th May, 2012

MATERIAL TRANSPORTATION FOR SICO

Background:

SICO is one of the leading manufacturers of finished steel in world. **You have been hired as the Operational Consultant by SICO to help them optimize the logistical costs**. One of your first assignments is to optimize the procurement process for coal. Following information is gathered during your discussions with the procurement manager for coking coals.

Summary of discussion with Procurement Manager:

SICO imports two different types of coking coals (coal used for making coke, which is a major input for steel production) from Australia. The two varieties of coking coals are called Grade-A coal and Grade-B coal (for lack of better words!). The monthly demand for both the types of the coking coals at the SICO factory works is assumed to be deterministic and known.

SICO had been using only one variety of imported coal, i.e., grade-A coal till now. But in the coming months, the top management has decided to introduce a new, cheaper variety of coal called grade-B coal. The ash content (level of impurity) of grade-B coal is higher than the ash content of grade-A coal.

Grade-A coking coal is loaded at port Hayport and Grade-B is loaded at port Gladstone, both in Australia. At the domestic end, the coals can be unloaded at two ports: P and Hd, from where they would be brought to SICO's factory works by railroads. The two ports are so chosen that the cost of land hauling of the material should not become too high.

It may be noted that ships with more than 60,000 metric ton (MT) capacity cannot be handled by either of the unloading ports due to insufficient draft in the sea. Note that draft is the depth of the sea at port and higher draft would allow larger capacity vessels to enter the port. While P can handle vessels with up to 60,000 MT capacity, the draft at port Hd restricts the shipment size to about 35,000 MT capacity. Given this constraint of the ports, the material can:

1. be brought in smaller ships and unloaded completely at port Hd. (with no business at port P)
2. be brought in larger vessels and unloaded completely at port P. (with no business at port Hd)
3. be brought in larger vessels, unloaded partially at port P and the remaining at port Hd.

The more the number of unloading ports, the more will be the overall costs. For every additional unloading port, extra fixed freight charges on the overall tonnage of the vessel have to be incurred by SICO. Note that the cost of hauling the material from port Hd is less than the cost of hauling the material from port P because of the proximity of port Hd to SICO's works. Material is hauled from the two ports to SICO by the state-owned railway company. Typically, Box-N type of wagons having a capacity of about 60 MT is used for this purpose.

Material unloaded from the vessel at the ports is stored at the yard space available for SICO. Storage space costs associated with these stocks is almost negligible. Other stores administration expenses on a per MT basis are negligible, because of the huge quantum of materials stocked at the stockyard.

In addition, the management has decided to not unload more than one variety of coal at a single port in case both P and Hd ports are selected for operations. In particular, port Hd is dedicated to handle grade-A coal and thus a vessel carrying two varieties of coal would unload grade-B coal at port P and grade-A coal at port Hd. Port P can handle both varieties of coal. This is done in order to avoid the mixing up of two varieties of coal by the port laborers in the absence of any physical distinction.

The major cost components are:

1. Fixed costs for chartering the vessel
2. Cost of the raw materials
3. Cost of unloading and handling the materials at ports and at the factory works
4. Cost of railroad hauling from P or Hd to SICO’s factory works
5. Inventory carry costs (capital costs for paid goods) for both the coals

Since the maximum size of any shipment that can be handled by either of the local ports is 60,000 MT, management team at SICO has decided in favor of *panamax* vessel to bring the coal from Australia. After a detailed evaluation, it was found that bringing in smaller vessels of coal would be more expensive due to the high fixed costs. A panamax vessel has seven huge drums (or hatches) and each individual hatch can accommodate about 8,500 MT of coal. Needless to state, only one variety of coal can be stored in a single hatch. Management is also particular that only full vessels are ordered every time. No vessel should be brought in with any partially filled hatches. The following table gives the various costs elements:

Item	Cost
Cost of Grade-A coal	€ 80 per MT
Cost of Grade-B coal	€ 55 per MT
Vessel contracting cost	€ 200,000 per occasion
Fixed Cost of unloading at P	€ 25,000 per vessel
Fixed Cost of unloading at Hd	€ 20,000 per vessel
Variable Cost of unloading at P	€ 1.00 per MT
Variable Cost of unloading at Hd	€ 1.10 per MT
Cost of loading and railroad hauling from P	€ 17.00 per MT
Cost of loading and railroad hauling from Hd	€ 7.50 per MT
Interest rates (for inventory carrying costs)	6% per annum

The demand for the two coals across the days of the month is uniform, but the demand of the two coals over different quarters is given below. Remember that grade-B is a new variety and is planned to be used only starting July 2011.

Period	Grade A coal consumption, in 000 MT	Grade B coal consumption, 000 MT
Jun 2011	64	0
Jul-Aug 11	168	14
Sep-Nov 11	134	78

Dec 11–Feb 12	141	88
Mar – May 12	150	86

Assume that the payments for the vessel and the raw materials is made on the day of arrival of the vessel at the first port of entry. After the arrival of the vessel at port P, material from both P and Hd arrive simultaneously after 3 days, which includes the time to unload from vessel, load into railroad wagons and the running time of trains. Vessel spends 10 days in high seas after leaving Australia and before arriving at the first of SICO's ports. Exporter in Australia takes 5 days to process SICO's orders. Assume that the required safety stock for two coals is 10,000 and 5,000 MT. The stocks at the end of day on 31st May 2011 is 48,000 MT and 0 respectively for grades A and B coal.

Challenges:

SICO never had any problem with reorder because the procurement manager would call up the Australian exporter exactly 18 days (accounting 5 days for order processing, 10 days for vessel transport and 3 days for railroad transport) before he percieved that the stocks of grade-A coal would reach just above 10,000 MT. Three hatchets of panamax vessel would be unloaded at port P and the remaining 4 at port Hd.

However the problem complicates as there are two items now. It is possible that one item nears stock-out, while the other item might stock-out shortly later. Given the high fixed costs of chartering the vessels and also the inventory carrying costs, the coal ordering process must be evaluated. Bringing in full shipments of two coals separately as and when the reorder level is hit may not be optimal. So the basic question for you to address is **when and how much** quantity of each coal should be ordered by SICO so that there is never a stock-out and obviously the total costs are minimized. As a smart consultant, you may also find out and convey the implications (on the costs) of the decisions taken by the management team – such as decision to restrict grade-B coal at port P and the decision to bring in ONLY full shipments etc. You may also evaluate the impact of outside factors such as lead time (defined below) in your report to the management.

Hint:

You have a discussion with your supervisor following your discussion with the procurement manager, He provides you with the following insights which may be helpful with your analysis:

- Inventory costs: It is the cost of holding any material. Imagine if you could put the money in a bank or some other deposit instead of paying for the material. It is calculated as follows:
  Inventory carry cost = (cost of the raw material) x (rate of interest) x (number of days)
  For example, carrying 60 MT of an item costing € 100 per MT would incur the following inventory carrying cost for 10 days at 6% interest rate

$$60 \times 100 \times \frac{6}{100} \times \frac{10}{365} \qquad = € 9.86$$

- Lead time: Lead time is the time required for the material to arrive at the factory works after an order is placed. In this case, it is 18 days – deterministic and uniform. In reality, it may neither be known beforehand nor consistent. To safeguard against unexpected lead time, safety stock (in this case 10,000 MT of grade-A coal and 5,000 MT of grade-B coal) is usually held.
- Amount of inventory on a particular day for a particular commodity is calculated as:

  Inventory held today = Inventory held yesterday – amount consumed today + amount arrived at the factory works today, if any

- Not many shipping options are available after the different constraints imposed by the management. Some other options may bring the same material at the works factory, but at a higher cost and thus can be discarded. Given that only full shipments can be ordered, following are the only possible options in any optimal sequence of orders:
  - Full shipment of grade-B coal unloaded at port P
  - Full shipment of grade-A coal with three hatches unloaded at port P and four at Hd
  - Six hatches of grade-B coal unloaded at port P and remaining grade A at port Hd
  - Five hatches of grade-B coal unloaded at port P and remaining grade A at port Hd
  - Four hatches of grade-B coal unloaded at port P and remaining grade A at port Hd
  - Three hatches of grade-B coal unloaded at port P and remaining grade A at port Hd

One of your tasks is to **explain** why several other shipping options, for example a full shipment of grade-A coal with four hatches unloaded at port P and three at port Hd, need not be considered as an option for the optimal solution.

- Compute the logistics costs and inventory holding costs for each of the option. It is not difficult to see which options are more cost effective and why.
- Your next task is to formulate a mathematical MIP model and solve the same with a MATHPROG as learnt in the class.
    - Different sets that you may use are options, type of coal and days
    - Logistics cost for each option needs to be computed based on the cost structure. This will be one of the major input parameter
    - Demand (or consumption) of different types of coal is another input parameter. Consumption will be across days and thus it will be a two dimensional matrix. Since they vary only by months or quarters, it may be useful to prepare this data for every day for one whole year using a spreadsheet. Copy the spreadsheet table in your plain text data file in the correct format. MATHPROG user guide may be helpful. (http://www.cs.unb.ca/~bremner/docs/glpk/gmpl.pdf)
    - Objective function (minimization) consists of two components:
        - Cost of inventory, plus
        - Cost of transportation (ship + rail), minus
- Run the mathprog model with the following command

  glpsol --model <*model_file_name*> --data <*data_file_name*> --output <*output_file_name*>

  However you have the option of adding several other parameters. For example, if your model takes too long, you can set a limit on run time with the tmlim option. Tmlim 120 will have the model running for 120 seconds and give you the best result after this time.

  glpsol --model <*model_file_name*> --data <*data_file_name*> --tmlim 120 --output <*output_file_name*>

  For a detailed list of options, refer http://www.maximal-usa.com/solvopt/optglpk.html

This tutorial is prepared and designed by Prem Kumar Viswanathan for the "Decision Aid Methodology" course for Spring 2012 session.