1.011 Project Evaluation
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Assigned: February 9, 2005
Due: February 22, 2004

Assignment 2
"Developing Cost and Revenue Functions"

Canals were among the first major civil engineering projects in the United States. In the era before railroad or truck transportation, land transportation was cumbersome, slow, and expensive. Water transportation – when available - was much cheaper, more reliable, and provided the only means of handling large volumes of freight, which of course was why cites grew up at the best harbors and along the major navigable rivers. The first canals simply bypassed rapids so as to avoid costly transshipment of goods. Later canals, such as the Middlesex Canal, linked major cities to their hinterlands. More ambitious projects, such as the Potowmack and Erie Canals sought to open up western regions and thereby promote development (not to mention the importance of the port city whose citizens promoted the project).

The width and depth of a canal and the size of the locks determine the size of the boats that can use the canal. The deeper and wider the canal, the more material that must be excavated and the more expensive the project. The larger the locks, the more expensive they become and the more water that is required to operate the system. Hence, there are fundamental design issues concerning the size of the canal and the type of boats that will be accommodated.

Some of the early canals could only handle small boats with a capacity on the order of 15 tons; these boats required a draft of only 12 inches when loaded. Larger canals could handle larger boats, e.g. boats that could carry 75 tons along canals providing more than 4 feet of draft. The channel - at the bottom of the canal - must be wide enough for two boats to pass (or there must at least be periodic basins where opposing boats can pass).

1. **Capacity Model (30%)**

The capacity of a canal (maximum throughput measured in tons of cargo) could be estimated for various time periods, e.g. a peak day with 12 hours of operation; a peak summer month with 12 hours operation, 7 days/week; for a year, with operations ceasing during the winter and during major storms. Boats can tie up for the night at either end of the canal or at frequent locations along the length of the canal; as a result, boats will likely be dispersed all along the canal at the beginning and end of the day.

a. Develop a model of a canal's capacity as a function of the characteristics of the canal, the boats, and the operating characteristics (e.g. speed through the canal, cycle time of the locks [i.e. the time required for one boat to pass through the lock], hours available for operation per day and week, and months available for operation per year).
b. Use this model to estimate the capacity (tons/month) of a canal that is 30-miles long, has 10 locks (1 lock at each of 10 locations), is wide enough for 2 boats to pass assuming that it is designed for a) 15-ton, b) 25-ton, or c) 75-ton boats.
c. What are the most important factors affecting the capacity of the canal?

Operating Cost Model (30%)

Canals competed with horse-drawn wagons:

"The advantages of canal travel over wagon transport were obvious at once. One horse, for example, could easily draw 25 tons of coal on the canal. On land the same horse could pull only 1 ton. One team of oxen could pull 100 tons, an amount that would take eighty teams on land. In the first eight months of the canal's operation, 9,405 tons were carried at a cost of $13,371. The cost for such a shipment by land would have been $53,484." Daniel L. Schodek, "Landmarks in American Civil Engineering", MIT Press, p. 12

These estimates of operating cost for this 27-mile canal can easily be converted to the cost/ton or the cost/ton-mile of transporting freight by canal boat or by wagon.

We would like to estimate the benefits (cost savings) from constructing a canal that would attract traffic from wagons. Assume that the cost/ton-mile for wagon transport is constant. Assume that the operating costs for a canal are based upon typical values for the early 19th century:

- Cost for the 2-person boat crew ($1/day each, for 10 working hours)
- Cost for the teamster and the horse ($1/day each)
- Cost for the boat ($2/day for 15-ton; $2.50 for 25-ton; $5/day for 75/ton boats)
- Cost for lock operations ($2/day for an operator and routine maintenance)
- Cost for canal and embankment maintenance ($40/year per mile)
- Average speed (3 miles per hour along the tow path)
- Average time per lock (12 minutes for small, 15 for medium, and 20 for large boats)

a. Develop a spreadsheet model for estimating the cost per ton and cost per ton-mile of moving freight along a canal similar to the Middlesex canal. The traffic volume (tons/year), length of the canal, the number of locks, hours of operation per day, days of operation per week, and months available for operation should all be variables in your model.
b. Use your model to estimate the operating cost for each of the 3 sizes of boats assuming that annual traffic varies from 10,000 to 100,000 tons per year.
c. What are the most important factors affecting the operating cost of the canal?

[NOTE: question 2 requires you to estimate the fixed and variable costs of operations; to get the total cost per ton, you must allocate the fixed cost to the tonnage that is handled.]

3. What Size Boats? (40%)

Assume that the state legislature (which has allowed you to build the 30-mile canal) has authorized you to charge no more than 50% of the wagon costs per ton-mile, no matter what size boat you use. Further assume that you can raise money for investment that equals 10 times the annual operating profits (i.e. if projected operating profits were $10,000 per year, you could raise $100,000 to construct the canal). The Middlesex Canal cost $528,000, which is just under $20,000 per mile. To keep the calculations simple, assume that the per-mile construction costs would be $20,000, $25,000, and $30,000 to handle the three sizes of boats (and further assume that the annual costs for repaying construction loans would be 10% of the construction costs, i.e. $2,000, $2,500, and $3,000 per mile respectively). How much annual tonnage would be needed to justify building a canal that handled a) 15-, b) 25- or c) 75-ton boats?

[NOTE: question 3 asks for breakeven analysis of the type described in the text. The question is how much tonnage is required so that the operating profit (revenue per ton – variable cost per ton) is sufficient to cover the fixed costs of the canal plus the annual capital costs).]

4. What Role for Analysis? (Bonus – 10%)

Describe how analysis related to one of the following disciplines could be used to improve your model of the performance of the canal: fluid mechanics; materials science; structural mechanics; soil mechanics; physics; probability & statistics; biology.