1.011 Project Evaluation
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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 spreadsheet 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?

2. 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 or $2/day total)
- 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 at a particular level of traffic, 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 (thus operating profits would have to be at least $2,000, $2,500, and $3,000 per mile respectively before the investors would be willing to provide enough funds to construct the canal). How much annual tonnage would be needed to justify building a canal that handled a) 15-, b) 25- or c) 75-ton boats?

[NOTE: you can approach this problem as a breakeven analysis. The contribution per ton (i.e. revenue per ton – variable cost per ton) multiplied by total tonnage must be sufficient to cover the fixed operating costs of the canal and leave enough operating profit to justify the investment.]

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

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

Thoughts on Spreadsheet Design

1. Title: have a title for the spreadsheet and for each exhibit

2. Appearance: set up the spreadsheet so that you can print exhibits for your term project

3. Control panel: have a section where it is easy to enter key variables and see key results

4. Tables: a table that shows results for various sets of inputs can be very useful to have

5. Level of detail: you do not have to be any more detailed than "Skyscraper"; if you do not have the data that you would like, then you should estimate what seem to be reasonable numbers for costs and benefits (be sure to explain which numbers are estimates and why you believe these estimates are reasonable; if you have good numbers, be sure to show the source) - this assignment is concerned with your ability to design a spreadsheet and you will be able to get better inputs as you progress with your term projects

6. Graphs: it is often helpful to create one or more graphs to display cost, benefits, comparisons of options, or sensitivity analysis

7. Interpretation of Results: it may be useful to introduce cost effectiveness measures for some projects (e.g. $/resident, or $/transit trip, or some other measure that puts the numbers into context)

8. Color, borders, etc: this can make your results sparkle - but don't spend a lot of time on this and don't let the style overwhelm the substance

9. Text: remember, you can write descriptive paragraphs in the spreadsheet

10. Detailed calculations vs. results: you may want to move the details to a part of the spreadsheet that you don't have to print or view; make some portions of your work accessible in tables and charts that are easily viewed and printed.

11. Level of precision: remember that your analysis involves many different estimates, some of which are bound to be rather imprecise. When you show results, be sure not to use too many significant figures. Spreadsheets allow you to specify the number of decimal places, and they also allow you to round off the numbers that are displayed. You can also show results in, say, $ million or even $ billion and thereby avoiding having to show too many significant digits.

Resource: Project Evaluation: Essays and Case Studies
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