

OPTIMUM INCREMENT FOR CAPACITY EXPANSION – BASE CASE

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GOALS:

1. Learn about capacity expansion problem and its possible optimal solution
2. Practice in use of NPV analysis on spreadsheets

GENERAL PROBLEM DESCRIPTION:

Alan Manne (1967), in his book “Investments for capacity expansion”, presents an analysis for calculating optimal sizes of plant capacity to be added at several points in time. Under growing demand and economies of scale there will be a choice between several time streams of expenditure. For example, if a single large plant is built, advantage can be taken of economies of scale in construction, however it requires a large initial investment. If several smaller plants are built at different times, you may sacrifice some production economies but you also gain by delaying part of the capital investment and avoiding interest payments.

In general, Manne’s result is that new capacity should be added in fixed increments that depend on the intensity of the economies of scale and on the discount rate. [If there are no economies of scale, the best policy is to build “just in time” according to need. As economies of scale become more important, it is worthwhile building larger, even though that means you have to pay immediately for capacity you will only use later.] These fixed increments represent demand growth over a specific period, known as the cycle time for the addition of capacity.

To compare expenditures incurred at different dates, Manne uses the discounted cash flow criterion (present value). In this exercise you will replicate his analysis.

MODEL BRIEF DESCRIPTION:

In his analysis, Manne assumed that (1) demand grows linearly over time and (2) there are no imports in the market. Hence, demand has to be satisfied at all times by internal production. This exercise provides you with a model (Optimal Capacity Expansion base case.xls), based on the same assumptions, that displays cash flows over 100 years. An infinite time horizon could also be used.

The model uses discrete rather than continuous time analysis implied in Manne’s analytic version. Specifically, it uses an annual discount rate so adjustments are needed to compare results produced with continuously compounded discount rate. The continuously compounded discount rate (r_c) is related to the annually compounded discount rate (r_a) according to the formula: $r_a = e^{(r_c \cdot t)}$ for $t = 1$ year.

The model gives results in terms of years rather than in fractions of a year as Manne did.

ACTIONS:

1. Open the model and read the “read me” worksheet for model details and necessary settings on your machine.
2. Start with an initial capacity 100 units per year, 5 units/year/year demand increments, 6 years cycle time, parameter $a = 0.7$, a constant of proportionality $k=1$ and a discount rate $r=10.5\%$ (equivalent to 10% compounded continuously discount rate). What is the NPV?
3. To test how the NPV result changes with different input assumptions using a data table. One variable data table tests the model by changing only one variable. Use input cycle times in the range 1 to 20 years and run the model.
4. Plot the data table results in a graph of NPV versus cycle time to define optimal cycle time.

5. Repeat step 2 through 4 using demand increments of 2 and then 8 units/year/year.
6. Determine the effect of the economies of scale parameter a on the optimal cycle time for different discount rates. For this step you will need to use a two variable data table. Use a values in the range 0.4 to 0.95 and cycle times in the range 1 to 20 years. Plot a graph of optimal cycle time versus a for a chosen discount rate.
7. Examine the effect of time horizon on your results. Do this by changing the formula in the NPV of costs to sum only 20 years and run the model. Note the differences on the optimal cycle times on your graphs. Explain why one is below the other, why one is smooth and the other not.

DISCUSSION QUESTIONS:

1. What is the optimal cycle time for capacity addition predicted by the model with initial assumptions as stated above in step 2? Compare your result with Manne's figure 2.6, chapter 2 –found in Appendix at the end of this document.
2. What is the effect of the economies of scale parameter a on the optimal timing? Compare your results with figure 2.4, Manne chapter 2 – found in Appendix 1 at the end of this document.
3. What is the NPV of costs with demand increments 8 units/year/year and 2 units/year/year? Calculate the average NPV and compare this result with the result you had with demand increments of 5 units/year/year. Are these values the same? Explain this observation.
4. What is the effect of using a 20 year time horizon in your model?

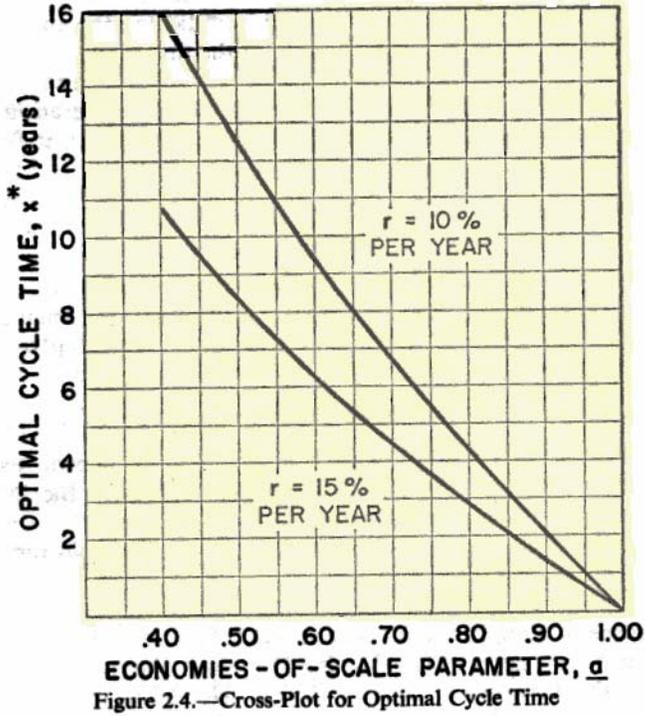
TAKE AWAYS:

1. Under a given linear demand growth rate the optimum strategy is to build a plant every 7 years of size x (where x is given in terms of the growth rate). For example for growth rate = 5 units/year/year the optimum plant size is $7 \cdot 5 = 35$ units/year.
2. The optimal cycle time is affected by the discount rate and the economies of scale. It is smaller when:
 - a. the economies of scale are smaller (since economies of scale are the factor that motivates larger chunks of capacity); and
 - b. the discount rate is the higher (since a higher discount rate penalizes early investments).
3. The NPV calculated for average growth rate (e.g. 5 units/year/year) is not equal to the average NPV calculated for a distribution of growth rates (8 and 2 units/year/year that when averaged equal 5 units/year/year). This is a common mistaken assumption known as the "flaw of averages". [The mistake is to assume that the value of a function obtained using an average or expected value of a quantity – such as a 5% growth rate – equals the expected value of the function resulting from using the distribution of the quantity. In short: $EV [F(x)]$ does not equal $F[EV(x)]$]

APPENDIX: MANNE'S GRAPHS

Scanned from Alan Manne (1967) Investments for Capacity Expansion: Size, Location, and Time-Phasing, MIT Press, Cambridge, MA (USA)

The effect of discount rate and economies of scale on the optimal cycle time.



The optimal cycle time ($x^* = 6.75$ years) with a linear demand growth

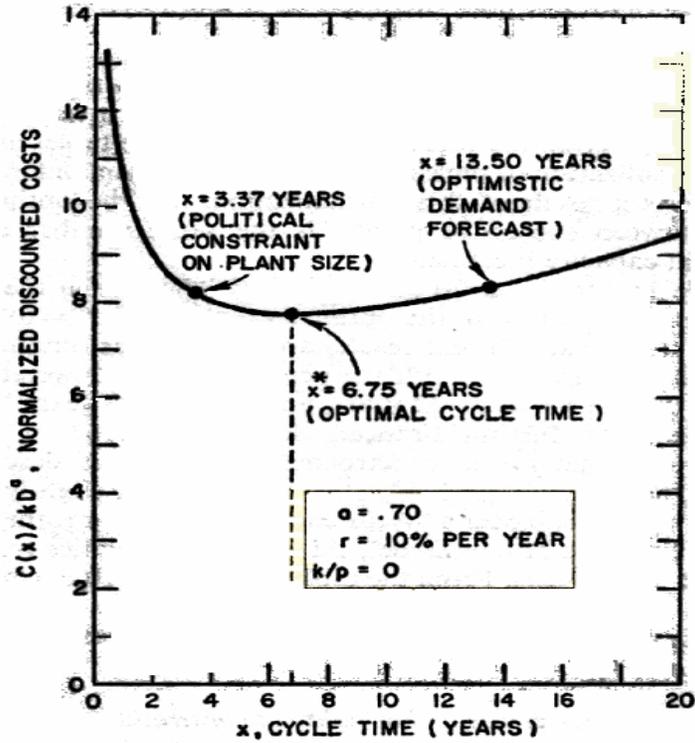


Figure 2.6.—Discounted Cost Function