Basic Economic Principles and Deciding Among Alternatives

12[3]

In the business world, the rearview mirror is always clearer than the windshield.

Warren Buffett

In economics, the majority is always wrong.

John Kenneth Galbraith

Art is the beautiful way of doing things. Science is the effective way of doing things. Business is the economic way of doing things.

Elbert Hubbard

12.1 Chapter Purpose

The purpose of this chapter is to familiarize you with the concept of interest rates (or time value of money) and then give you the capability to manage simple but engaging decision-alternative problems related to real-life situations and process engineering. We will keep it simple in terms of economic concepts, but you will face interesting situations from everyday life and, additionally, stimulating and thought-provoking problems related to chemical and bioprocess engineering. We will continue to learn about and engage with these broad fields. Through the problems, you will become familiar with different loan options and learn how to compare them and improve your effectiveness as a rational consumer. The core of the chapter is comprised of problems where you, as an engineer, will need to compare different alternatives and make decisions mainly based on economic considerations. You will face questions where your technical expertise and knowledge of economics will be challenged to compare, for example, offers from two or more companies to replace reactors at a processing plant. At this stage, the problems will focus on economic analysis. For us, though, as future process and bioprocess engineers, the technical aspects of the project are more relevant, so we will leave this matter for future courses.

Our challenge is to teach you just a few concepts, as has been our approach throughout the book, and add maybe just one more (interest rates). Then we will present stimulating and motivating examples from everyday life and, more importantly, from situations one might encounter in chemical and bioprocess engineering.

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12.2 Understanding What Economics Is

Economics is a social science. As Professor Paul A. Samuelson (1915–2009) rightly stated, economics is the oldest of the arts, the newest of the sciences, in fact, the queen of the social sciences. It is difficult to briefly define economics. Quoting, again, Professor Samuelson, the economics concept can be generalized through the following definition:

> Economics is the study of how men and society end up choosing, with or without money, employment of productive resources (scarce) that may have different uses to produce various commodities and distribute them for consumption, present or future, between various individuals and groups that make up society, analyzing the costs or benefits of improving patterns of resource distribution.

For the purposes of this book, we will be concerned with understanding and familiarizing you with the concept of economics and focus on what is of interest to future process and bioprocesses engineers. The scheme presented below gives us the opportunity to understand all the interrelationships in the economy and identify what aspect we will focus on in this first year as novice prospective engineers.

12.3 What You Will Be Learning

Within this big picture (Fig. 12.1) our humble objective is to provide you with the capability to approach real-life and engineering problems, situations where it is necessary to decide among different alternatives that are technically equivalent. In real-life engineering you will face several situations where the final decision will depend on your technical and economic analysis. For example, a manufacturer is offering you more efficient and automatic equipment to replace your current

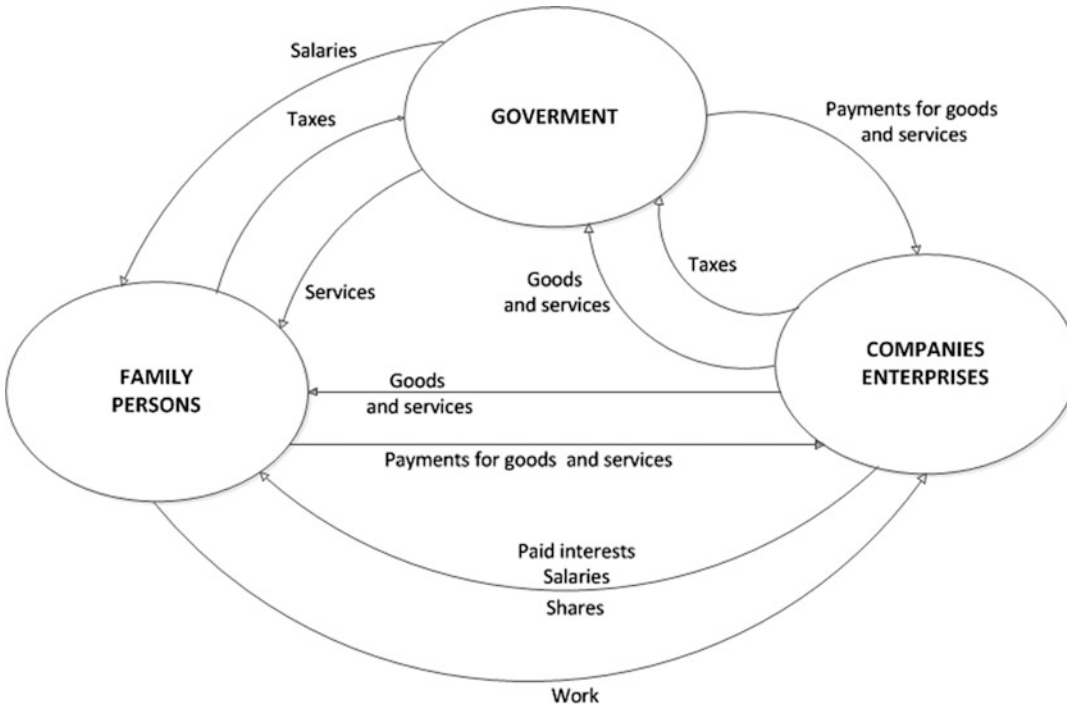

Fig. 12.1 The scheme presents all the inter-relationships of the economy in our society

equipment. What do you do? First, you carry out a technical analysis and check all the specifications given by the manufacturer and how they fit and work with the existing process and quantify how the new process will improve the existing process. Second, you perform a careful economic evaluation among the alternatives before making your final decision.

At this stage, we will introduce and illustrate the concept of interest rate (compound interest rate) and, in addition, provide a few elementary formulas of financial mathematics (Sect. 12.5) to empower and give you the capacity to solve all the problems presented in this chapter.

12.4 What Is the Interest Rate? Some Simple Calculations

The interest rate represents the monetary value of the ability to use money over time. As an analogy, when you use a house, a car, equipment, or other item that you do not own, you pay a fee: in this context, it is called rent. In simple terms, interest is what I need to pay in order to be able to use some specific amount of money by a certain time. Although many people have a negative perception of the interest rate, in reality, for the same people, it is natural to pay rent for an apartment, a car, a piece of equipment, etc. (which in turn have an equivalent cash value). Therefore, it is logical that we should pay "rent" for using an amount of money that we borrowed from, in most cases, a bank (or equivalent institution). In the same way, it is logical to receive money when you rent out your house or when you lend money to someone. The question is how much to charge. At this point, it is important to introduce the concept of opportunity cost. For example, if someone borrows \$1,000 from you for 1 month, how much will you charge the person to use your money for this period of time? Assuming that the only alternative is to deposit the money in a bank account, your opportunity cost is the amount that the bank is willing to pay you to use your money. In general, opportunity cost refers to the best alternative use of your resource (e.g., house, land, money, time).

As mentioned, money has value throughout time. If you want a loan for some specific time period—say 1 month—then you need to pay interest to use, for your own benefit, this money for 1 month. For example, if you want a loan of \$$L$ for 1 month and the interest rate is r % per month (compound interest), then after 1 month you need to return \$$L_{\mathrm{F}}$ to the lender, where the financial mathematical equivalence between L and L_{F} is

$$L_{\mathrm{F}} = L\left(1 + \frac{r}{100}\right)^{1}, \tag{12.1}$$

where L_{F} is the future value (\$), L is the present value (\$), and r is the monthly interest rate (%).

In words, in this case, the future value (L_{F}) is equivalent to the present value (L) multiplied by 1 plus the interest rate divided by 100 (because the interest rate was given as a percentage) with an exponent equal to 1 because the loan was for 1 month. If the interest rate is given in decimal form, then the financial mathematical equivalence between L_{F} and L is

$$L_{\mathrm{F}} = L(1 + r_{\mathrm{d}})^{1}, \tag{12.2}$$

where L_{F} is the future value (\$), L is the present value (\$), and r_{d} is the monthly interest rate in decimal form (where $r_{\mathrm{d}} = r/100$).

If the loan is for n months, then after n months you need to return

$$L_{\mathrm{F}} = L\left(1 + \frac{r}{100}\right)^{n} \quad \text{or} \quad L_{\mathrm{F}} = L(1 + r_{\mathrm{d}})^{n}. \tag{12.3}$$

Simple and compound interest

It is necessary to distinguish between simple and compound interest. Simple interest is paid only on the deposit (L), whereas compound interest is where the bank pays interest on the principal deposit and the accumulated interest on the principal. Equation (12.3) is the future value of L calculated with compound interest.

Henceforth, all calculations in this chapter are carried out assuming compound interest.

Warm-up example 1. You go to a bank and apply for a $1,000.00 loan. (a) How much you will need to pay the bank back after 6 months if the monthly interest rate is 1.5 %? (b) Is it worth taking out the loan? (c) How does your answer in (a) change if another bank offers you a monthly interest rate of 1 %?

Solution

(a) If we call L_F the amount of money that you need to pay the bank after 6 months, then

$$L_F = 1,000\left(1 + \frac{1.5}{100}\right)^6 = 1,093.44.$$

The result shows you that the use of $1,000 for a period of 6 months (at $r = 1.5$ %) has a cost of $93.44.

(b) It depends; maybe a monthly interest rate of 1.5 % is a bit too high. There are different ways to determine whether or not it is worth it, but, for example, if you are investing this money in a project and the profits from the project are expected to be much higher than $93.44, then it is worth applying for this loan, unless you have another option from a different bank with an interest rate lower than 1.5 % [see answer (c)].

(c)
$$L_F = 1,000\left(1 + \frac{1.0}{100}\right)^6 = 1,061.52$$

Warm-up example 2. You are looking for a loan of $1,000 from a bank with the constraint that you need to return the money to the bank within 1 year (12 months). The bank's loan officer tells you that you are an excellent client and you deserve a very low interest rate. So the loan officer tells you that credit has been approved for you and that you need to pay the bank $1,100 within 1 year. (a) What is the monthly interest rate? (b) What is the annual interest rate? (c) Find the equivalence between monthly interest rate (r_m) and annual interest rate (r_a).

Solution

(a) Based on (12.3), we can write

$$1,100 = 1,000\left(1 + \frac{r_m}{100}\right)^{12}, \tag{12.4}$$

where r_m is the monthly interest rate and the unknown in (12.4). As was explained in the previous chapter for similar calculations, we can use an Excel spreadsheet to obtain the value of r_m. It could be done graphically or using the Solver tool. Using the Solver tool we got r_m approximately equal to 0.8 %.

(b) In this case we can write

$$1,100 = 1,000\left(1 + \frac{r_y}{100}\right)^1, \tag{12.5}$$

where r_y is the annual interest rate and, at the same time, the unknown. In this case we get r_y analytically. Thus, $r_y = 10\ \%$.

(c) From (12.4) and (12.5) we get a general relationship between annual and monthly interest rate, as follows:

$$\left(1 + \frac{r_m}{100}\right)^{12} = 1 + \frac{r_y}{100}. \tag{12.6}$$

From (12.6) you can check that a 0.8 % monthly interest rate is equivalent to an approximately 10 % annual interest rate.

12.5 Financial Mathematical Equivalences

Keeping things simple, we will basically use two financial mathematical equivalences and the concepts of net present value (sometimes called net present worth) and annual equivalent benefits (or annual equivalent cost) (Sect. 12.6) to do all calculations for real-life problems and project evaluations. Although it represents a limitation (not using more concepts and equations), you will be amazed at the wide variety of real-life and engineering problems that can be solved with these few rather elementary tools. Thus, we continue to meet our objectives, which are to (a) teach just a few concepts and (b) captivate you with the diversity of problematic situations that arise in process and bioprocess engineering.

As mentioned, here we present two financial mathematical relationships and from both obtain a third one.

We set the following definitions:

F_V: Future value ($)
P_V: Present value ($)
S: Equal payments ($)
r: Interest rate per period (%) (could be months or years, depending on how the period is defined)
r_d: Interest rate per period in decimal form (could be months or years, depending on how the period is defined)
n: Number of periods (each period could be months or years, for example)

Relationship between future value (F_V) and present value (P_V)

Using the nomenclature defined in this section we can rewrite (12.3) and get

$$F_V = P_V\left(1 + \frac{r}{100}\right)^n \text{or, with the decimal form of interest rate, } F_V = P_V(1 + r_d)^n. \tag{12.7}$$

Relationship between present value (P_V) and equal payments (S)

$$P_V = \frac{S\left(\left(1 + \frac{r}{100}\right)^n - 1\right)}{\frac{r}{100}\left(1 + \frac{r}{100}\right)^n} \quad \text{or, with the decimal form of interest rate,}$$
$$P_V = \frac{S((1 + r_d)^n - 1)}{r_d(1 + r_d)^n}. \tag{12.8}$$

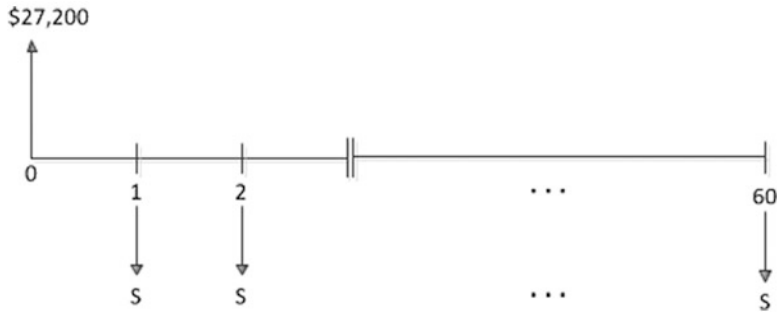

Fig. 12.2 Graphic representation (cash flow) of the Present value ($P_V = \$27{,}200$) and 60 equal payments (S)

From (12.7) and (12.8) we get a relationship between future value (F_V) and equal payments (S), as follows:

$$S = F_V \frac{\frac{r}{100}}{\left(\left(1+\frac{r}{100}\right)^n - 1\right)} \quad \text{or, with the decimal form of interest rate,}$$
$$S = F_V \frac{r_d}{\left(\left(1+r_d\right)^n - 1\right)}. \tag{12.9}$$

Warm-up example 3. You just graduated with a degree in chemical engineering (Universidad Técnica Federico Santa María, Chile) and found a good job in a large petrochemical company. Now, you are a bit restless, and you are going to want to buy a new car soon. So after a quick search you decide that the best option is a Ford Fusion SE hybrid sedan, which has a price tag of $27,200. Of course, you do not have the money to pay cash, but because of your new position in the petrochemical company, you qualify for a car loan from a bank. The loan officer at the bank offers you the loan ($27,200). You will need to make 60 equal payments with an interest rate of 1 % per month. (a) Draw a graphical representation of the problem. (b) What is the amount in dollars of each payment?

Solution

(a) Graphical representation (cash flow) (Fig. 12.2)

(b) As depicted in the graphical representation, we know the present value ($P_V = \$27{,}200$), the interest rate ($r = 1$ % per month), and the number of periods ($n = 60$ months), but we do not know the value of each payment (S). Therefore, substituting P_V, r and n into (12.8) we get

$$27,200 = \frac{S\left(\left(1+\frac{1}{100}\right)^{60} - 1\right)}{\frac{1}{100}\left(1+\frac{1}{100}\right)^{60}},$$

so $S = \$605.05$ per month.

Warm-up example 4. You need to buy a new refrigerator. Based on your initial research, you go to The Economy store. The advertised price on the fridge you are interested in is $1,000.00, and the seller gives you the option to buy the refrigerator with 24 equal monthly payments at an interest rate of 3.5 % per month. As a good Introduction to Engineering student, you analyze other options before taking a decision. Unfortunately, as a student, you have encountered several difficulties in

obtaining a loan from the bank. Finally, you find a bank that offers a very affordable interest rate (1 % per month), it but forces you to take out an insurance policy for $12 a month. (a) What is the value of the payments in The Economy store? (b) What is the value of the payments at the bank (excluding the insurance)? (c) What is more appealing: the loan from the bank (including the insurance) or the store?

Solution

(a) The Economy: here we know the present value ($P_V = \$1{,}000.00$), the interest rate ($r = 3.5$ % per month), and the number of periods ($n = 24$ months), but we do not know the value of each payment (S_{CE}). Thus, substituting into (12.8) we get

$$1,000 = \frac{S_{CE}\left(\left(1+\frac{3.5}{100}\right)^{24}-1\right)}{\frac{3.5}{100}\left(1+\frac{3.5}{100}\right)^{24}},$$

where S_{CE} represents the equal payments in The Economy store.
Thus, $S_{CE} = \$62.27$ per month.

(b) Bank (without insurance). Here we know the present value ($P_V = \$1{,}000.00$), the interest rate ($r = 1$ % per month), and the number of periods ($n = 24$ months), but we do not know the value of each payment (S_B). Thus, substituting into (12.8) we get

$$1,000 = \frac{S_{B}\left(\left(1+\frac{1}{100}\right)^{24}-1\right)}{\frac{1}{100}\left(1+\frac{1}{100}\right)^{24}}$$

Thus, $S_B = \$47.07$ per month.

(c) The loan from the bank is more appealing because you need to pay $47.07 per month plus the insurance ($12 per month) giving a total of $59.07 per month (lower than $62.27 per month in the commercial store). Notice that the comparison was made possible by the fact that the number of payments was the same in both alternatives.

12.6 Net Present Value (NPV) and Annual Equivalent Benefits/Cost (AEB or AEC)

We have already described and analyzed all the financial mathematical tools needed for our calculations to fulfill the purpose of the chapter. Using these basic tools, we now introduce two concepts that are important for comparison and decision among alternatives (real-life situations and engineering projects). First, the net present value is one of the most common tools to economically evaluate projects. One of the limitations of NPV is when you are comparing two or more projects with different lifespans. Although this difficulty can be remedied, it could be cumbersome. Second, the annual equivalent benefits/costs has the advantage over NPV that you can compare projects with different lifespans.

Although project evaluation is a whole branch of engineering, here we will limit its use to some elementary concepts to simply show potential implications and applications in process and bioprocess engineering.

Fig. 12.3 Cash flow for *NPV*

12.6.1 Net Present Value

The NPV represents all cash flows of a project (incoming and outgoing) evaluated at present ($t = 0$). If the sum of all cash inflows/outflows evaluated at present is positive, then the project is economically attractive. Typically when you are in the process of economically evaluating a project, you will have different cash flows (incoming and outgoing) at different times and with their own characteristics. The following schematic representation shows a typical project and then the financial mathematical equation to calculate its value through the NPV concept (Fig. 12.3).

$$\text{NPV} = -I + \frac{\text{CF}_1}{\left(1+\frac{r}{100}\right)^1} + \frac{\text{CF}_2}{\left(1+\frac{r}{100}\right)^2} + \cdots + \frac{\text{CF}_n}{\left(1+\frac{r}{100}\right)^n} = -I + \sum_{i=1}^{i=n} \frac{\text{CF}_i}{\left(1+\frac{r}{100}\right)^i}, \tag{12.10}$$

where NPV = net present value ($), I is investment ($), CF_1, CF_2, …, CF_n are the flow for each period (not necessarily positive) ($), and r is the discount rate (%).

In the particular case where $\text{CF}_1 = \text{CF}_2 = \ldots = \text{CF}_n = \text{CF}$, (12.10) can be written as

$$\text{NPV} = -I + \frac{\text{CF}\left(\left(1+\frac{r}{100}\right)^n - 1\right)}{\frac{r}{100}\left(1+\frac{r}{100}\right)^n}. \tag{12.11}$$

Warm-up example 5. Your friend Werner has an excellent idea but does not have the money to invest in this potential and novel project. After a careful analysis of all the cash flows, he explains to you that he needs $1.5 million. According to his estimations the annual cost of the project will be $70,000, with expected annual income of $320,000. At the end of the lifespan (10 years) the equipment items can be sold for $200,000. Would you be willing to invest in Werner's project? Consider an annual discount rate of 10 %.

Solution

To decide if the project is attractive, we will calculate NPV, where NPV ≥ 0 implies that the project is economically attractive.

Step I

Schematic representation

Step II

NPV calculation

First, the annual benefits are

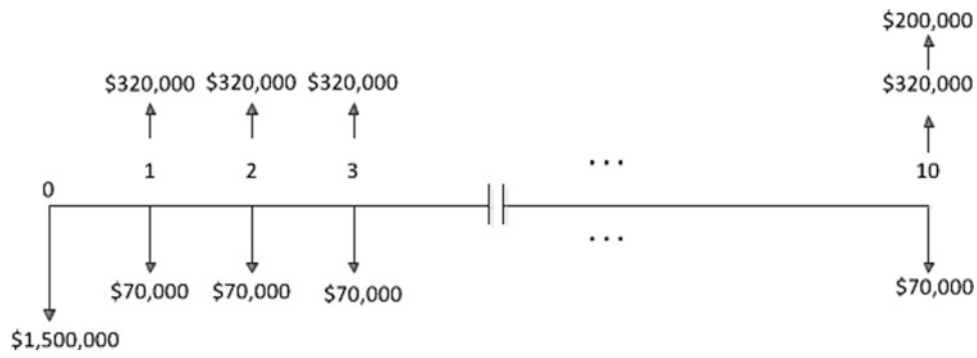

Fig. 12.4 Cash flow including all data

$$\mathrm{CF_i} = \$320,000 - \$70,000 = \$250,000.$$

Given that, in this case $\mathrm{CF}_1 = \mathrm{CF}_2 = \ldots = \mathrm{CF}_n = 250{,}000$, we can write the NPV equation (12.11) as follows:

$$\mathrm{NPV} = -1,500,000 + \frac{250,000\left((1.1)^{10} - 1\right)}{0.1(1.1)^{10}} + \frac{200,000}{(1.1)^{10}} = \$113,250, \tag{12.12}$$

where the third term in (12.12) corresponds to the present value of the equipment items sold at the end of the project (year 10). (NPV could easily be calculated using a spreadsheet.)

Step III

Analysis

As long as NPV ≥ 0, the project is attractive. In real-life problems it is advisable to do a sensitivity analysis answering questions like: what if the discount rate is 12 % (higher than the supposed 10 %)? What if the real investment turns out to be $1.7 million (higher than the estimated $1.5 million)? etc. For example, in Werner's project, if the required investment is greater than $1,613,250, then the NPV will be negative. In addition, if the discount rate is 12 %, the NPV will again be negative. With the data provided by Werner, small variations in his assumptions would put his project at risk.

Finally, as your business advisor I would recommend that you be cautious with respect to Werner's project!

12.6.2 Annual Equivalent Benefits/Cost

In a similar manner to NPV where all the cash flows were sent to the present ($t = 0$), here the idea is to obtain an amount of equal benefits/costs for each period of the project. An easy and straightforward way to obtain the annual equivalent benefit/cost is to first calculated the NPV and then, using (12.8), calculate the annual equivalent benefits/costs.

To learn more about the annual equivalent benefit/cost (AEB or AEC) calculation, we will refer to warm-up example 5 to calculate AEB. As mentioned, the first step is to obtain the NPV value. Thus, Fig. 12.4 shows the cash flows of warm-up example 5, and (12.12) shows that NPV = 113,250. Hence, rearranging (12.8) and using the appropriate nomenclature, we get

$$\text{AEB} = \frac{\text{NPV}\left(1+\frac{r}{100}\right)^{n}\frac{r}{100}}{\left(\left(1+\frac{r}{100}\right)^{n}-1\right)}. \tag{12.13}$$

Substituting into (12.13), NPV = \$113,250; $r = 10\,\%$; $n = 10$ years; and we get AEB = \$18,431 (the project is attractive because AEB ≥ 0). In (12.13), if NPV is negative, then AEB will be negative. As with NPV, the project will be attractive if AEB ≥ 0.

As mentioned, the advantage of AEB over NPV is that you can compare projects with different lifespans.

12.7 Comparing and Deciding Among Different Alternatives: Warm-Up Example

In the following example, we are invited to give our opinion and decide which project is better. Although both projects could be attractive, the required investment limits us to choose one of the two.

Warm-up example 6. A small pharmaceutical processing plant producing antibiotic pills wants to buy an automatic packaging machine, and company executives are analyzing two alternatives.

Determine which machine should be selected using an annual discount rate of 12 %.

Solution

As shown in Table 12.1, the lifespans of machines A and B are different. Thus, as suggested, we will use the AEC concept to decide which machine is better in economic terms. It is assumed that both machines have equal packaging capabilities.

Step I

Schematic representation (Fig. 12.5a, b)

Step II

AEC calculation

First, we will calculate the NPV per each alternative (machine A and B):

$$\text{NPV}_{\text{A}} = -200,000 - \frac{20,000\left((1.12)^{7}-1\right)}{0.12(1.12)^{7}} + \frac{30,000}{(1.12)^{7}} = -\$277,705;$$

$$\text{NPV}_{\text{B}} = -300,000 - \frac{6,000\left((1.12)^{10}-1\right)}{0.12(1.12)^{10}} + \frac{90,000}{(1.12)^{10}} = -\$304,924.$$

Table 12.1 Price and characteristics of machines A and B

	Machine A	Machine B
Price of machine (\$)	200,000	300,000
Annual maintenance cost (\$)	20,000	6,000
Residual value (\$)	30,000	90,000
Lifespan (years)	7	10

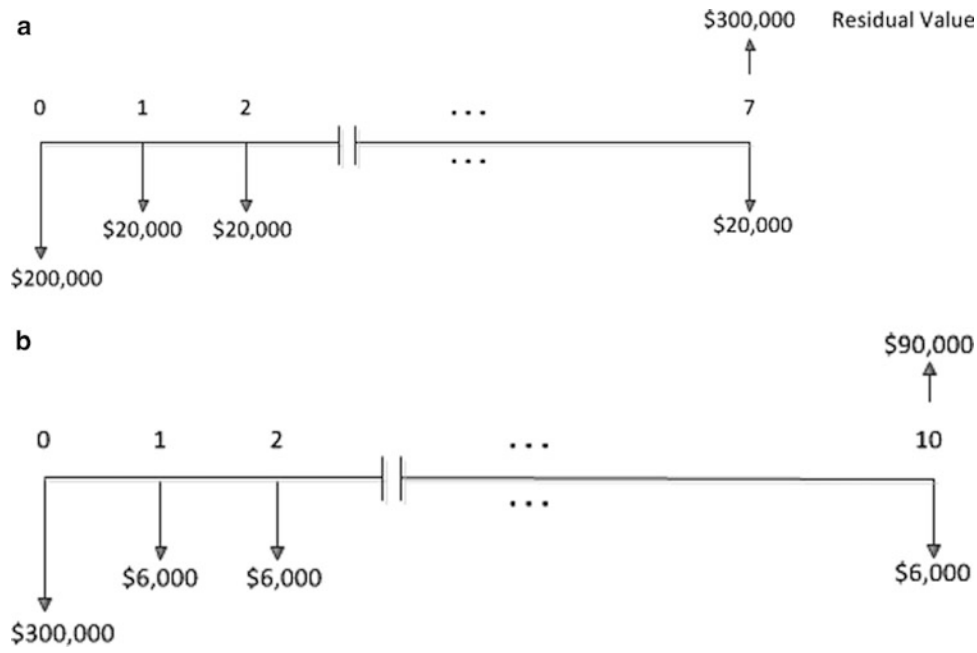

Fig. 12.5 (**a**) Cash flow for machine A. (**b**) Cash flow for machine B

Now using (12.13) we get the AEC for each machine:

$$\mathrm{AEC_A} = \frac{\mathrm{NPV_A}\left(1+\frac{12}{100}\right)^7 \frac{12}{100}}{\left(\left(1+\frac{12}{100}\right)^7 - 1\right)} = -\$60,850.10;$$

$$\mathrm{AEC_B} = \frac{\mathrm{NPV_B}\left(1+\frac{12}{100}\right)^{10} \frac{12}{100}}{\left(\left(1+\frac{12}{100}\right)^{10} - 1\right)} = -\$53,966.70.$$

Step III

Analysis

According to the AEC criterion, machine B is a better alternative than machine A because $\mathrm{AEC_B} > \mathrm{AEC_A}$, or less negative. It is interesting to note that if you directly use the data provided by the NPV calculations, machine A is better than machine B. Why? Although you can use NPV too, the requirement is that the projects should have the same lifespan or in some way equalize the lifespan of the evaluation. For example, if you carry out the first alternative ten consecutive times (70 years) and the second alternative seven consecutive times (70 years), now both evaluations show the same lifespan, 70 years (but, at least in this case, this is too cumbersome!).

12.8 Solved Problems

12.8.1 Real-Life Problems

1. **BMW [3]**. You are a recent Ph.D. graduate. As a specialist in mass transfer and process control a large international petrochemical company has an interest in your particular capabilities. Your starting annual salary will be $90,000. Now you are eager to fulfill one of your long-time dreams:

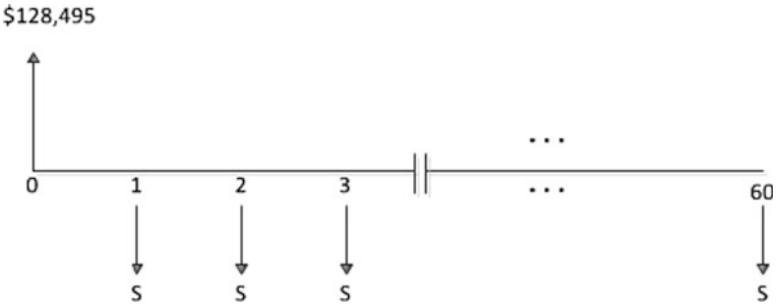

Fig. 12.6 Cash flow for the bank loan

to buy a new 2014 BMW Alpina B7. Of course, you cannot pay cash, but because of your new position at the petrochemical company, any bank will be very happy to give you a loan. The list price of the Alpina is $128,495. What will your monthly payments be if you get a loan that is payable in 60 months with an interest rate of 1 % per month?

Solution
The available data are the present value of the car ($P_V = \$128{,}495$), the monthly interest rate ($r = 1$ %), and the number of periods ($n = 60$). Then we can rearrange (12.8) and calculate the monthly payment (S).

Step I
Schematic representation (Fig. 12.6)

Step II
Payment calculation
Rearranging (12.8), we obtain

$$S = \frac{P_V\left(1+\frac{r}{100}\right)^n \frac{r}{100}}{\left(\left(1+\frac{r}{100}\right)^n - 1\right)} = \frac{128,495(1.1)^{60}0.1}{\left((1.1)^{60}-1\right)} = \$2,858.30/\text{month}.$$

Step III
Analysis
My only concern is that $2,858.30 per month will represent an significant portion of your monthly salary (almost 40 %).

12.8.2 Engineering Problems

2. **Wine cellar [4]**. A medium-sized wine cellar wants to replace an old bioreactor with a new and modern one. So far, it has received three offers:

At a similar annual cost the company prefers bioreactor C (because C is a modern and more reliable bioreactor). Similar means that if bioreactor C is no more than $2,000/year more expensive than the cheapest alternative, the company will buy bioreactor C. If the annual discount rate is 10 %, which of the bioreactors will the company buy?

Table 12.2

Equipment	Bioreactor A	Bioreactor B	Bioreactor C
Price ($)	80,000	120,000	150,000
Annual labor cost ($)	16,000	10,000	11,000
Annual maintenance ($)	4,000	3,000	–
Residual value ($)	20,000	40,000	80,000
Lifespan (years)	10	8	7

Solution

As shown in Table 12.2, the lifespan of bioreactors A, B, and C are different. Thus, as suggested, we will use the AEC (annual equivalent cost) concept to decide which bioreactor is better in economic terms. Consider that in this case it is not assumed that the bioreactors are equal, so to compare the alternatives, we will discount $2,000 to the AEC of bioreactor C.

Step I

Schematic representation (Fig. 12.7a–c)

Step II

AEB calculation

First, we calculate the NPV for each alternative (bioreactors A, B, and C):

$$\mathrm{NPV_A} = -80,000 - \frac{20,000\left((1.1)^{10}-1\right)}{0.1(1.1)^{10}} + \frac{20,000}{(1.1)^{10}} = -\$195,180,$$

$$\mathrm{NPV_B} = -120,000 - \frac{13,000\left((1.1)^{8}-1\right)}{0.1(1.1)^{8}} + \frac{40,000}{(1.1)^{8}} = -\$170.694,$$

$$\mathrm{NPV_C} = -150,000 - \frac{11,000\left((1.1)^{7}-1\right)}{0.1(1.1)^{7}} + \frac{80,000}{(1.1)^{7}} = -\$162,500.$$

Now using (12.13) we get the AEB for each bioreactor:

$\mathrm{AEC_A} = -\$31{,}764.7$/year,

$\mathrm{AEC_B} = -\$31{,}995.5$/year,

$\mathrm{AEC_C} = -\$33{,}378.4$/year.

If we discount $2,000 per year for bioreactor C, then the best alternative is bioreactor C.

Step III

Analysis

Again, as in warm-up example 6, if you directly use the data provided by the NPV calculations, then the best options in order are first C, then B, and finally A, contrary to the correct procedure using the AEC criterion, where the order is A, then B, and finally C. In conclusion, bioreactor C will be selected because, according to the problem statement, we can discount $2,000/year as bioreactor C is a more reliable piece of equipment.

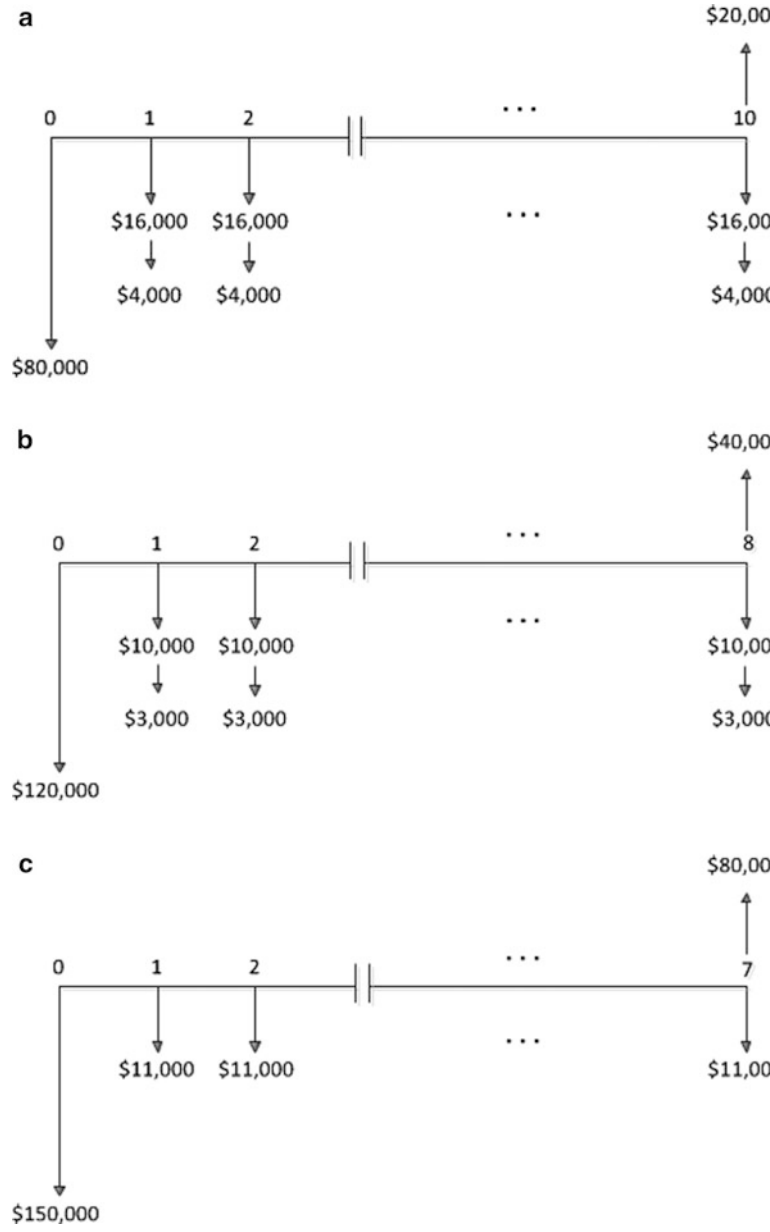

Fig. 12.7 (**a**) Cash flow for Bioreactor A. (**b**) Cash flow for Bioreactor B. (**c**) Cash flow for Bioreactor C

12.9 Proposed Problems

12.9.1 Real-Life Problems

1. **Superscreen TV [3]**. You have your eye on a 55″ HD TV, but you cannot afford its $1,500 price tag. The salesman offers you payment plans of 12, 24, or even 36 equal payments. The monthly interest rate in this mega store is 2.5 %. What is the monthly payment in each case: 12, 24, and 36 payments?
   A: $146.23, $83.87, and $63.68, respectively

2. **Superscreen TV 2 [3]**. Although you can make 36 payments of $63.68, before making a deal with the salesman, you go to the bank for a consumer loan. The executive tells you that because you are an old customer, you will receive a loan with an exclusive monthly interest rate of 0.6 %. (a) What is the monthly payment to the bank in each case of 12, 24, and 36 payments? (b) Any comments?
   A: (a) $129.9, $67.29, and $46.45, respectively. (b) First, normally it is much better to avoid payments. However, if you need a loan, the bank is normally the superior option.
3. **Interest rate [8]**. (a) Find a function that relates annual interest rate to monthly interest rate (decimal form). (b) Find a function to relate annual interest rate to semiannual interest rate (decimal). (c) Find a function to relate semiannual interest rate to monthly interest rate (decimal form).
   A: (a) $i_a = [(1 + i_m)^{12} - 1]$, (b) $i_a = [(1 + i_s)^2 - 1]$, (c) $i_s = [(1 + i_m)^6 - 1]$, where i_a, i_s and i_m are the annual, semiannual, and monthly interest rates, respectively.
4. **Interest rate 2 [4]**. (a) If the annual interest rate is 12.00 %, what is the monthly interest rate? (b) If the semiannual interest rate is 6.00 %, what is the annual interest rate? (c) If the semiannual interest rate is 6.00 %, what is the monthly interest rate?
   A: (a) ~ 0.95 % (0.950), (b) 12.4 %. (c) 0.976 %
5. **New house [4]**. You and your wife have found the house of your dreams. The only problem is that the price is $200,000. Because you are a good customer of a big bank, you can get a 20-year mortgage. The loan officer offers you a mortgage rate of $1,200/month for 20 years. What is the monthly interest rate that the bank is charging?
   A: ~0.32 %
6. **New house 2 [4]**. In relation to the previous problem, a $1,200 payment is a bit too high for you and your wife, but you have $40,000 in a savings account. Therefore, you will require a loan of $160,000. What is the monthly payment in this case?
   A: $961
7. **Money, savings, and interest rate [3]**. (a) How much money will you have in your savings account in 12 years if you deposit $350,000 today at an annual interest rate of 7 %? (b) How much money will you have in your savings account in 12 years if you deposit $350,000 today at an annual interest rate of 10 %? (c) How much money will you have in your savings account in 20 years if you deposit $350,000 today at an annual interest rate of, again, 10 %? (d) What do you think about these results?
   A: (a) $788,267.0. (b) $1,098,450. (c) $2,354,625. (d) One way to look at it is that the interest rate and the time you keep the savings have a big impact on your future savings. Just as we have continually recommended being steady and persistent with your study efforts, this also applies to your savings.
8. **Big machine [5]**. A company needs to buy a machine that costs $500,000. The bank offers the company a loan to be paid back in six equal payments every 6 months. If the annual interest rate is 12 %, what is the amount of each installment?
   A: $101,139
9. **Ferrari Testarossa [3]**. Your dad is dreaming of exchanging his old Ford Maverick (1973) for a new Ferrari Testarossa (2013). Because the Ferrari is very expensive, in his dreams, he has a detailed plan to secure a loan from the bank and pay it back in 8 years. The price of a used Testarossa is $80,000. Your father thinks he can afford that and goes to the bank to negotiate an $80,000 loan. After extensive paperwork and exhaustive revision of your father's records, the loan officer agrees to give him the loan through monthly payments (for 8 years) with an extraordinary annual interest rate of just 8 %. What is the monthly payment?
   A: ~ $1,120 (1,119.60)

10. **The power of savings [3]**. Imagine that your mom has been depositing money for you from the moment you were born (18 years ago). Regularly, each month, she goes to the bank and makes a deposit of $100.00. (a) How much money do you have in your savings account if the monthly interest rate has always been 0.8 %? (b) How much money do you have in your savings account if the monthly interest rate has always been 1 %?
    A: (a) ~ $57,385, (b) $75,786
11. **Mr. Smith [4]**. Mr. Smith is a very cautious and methodical man. He has been saving money for his retirement over the last 14 years. Every month he goes to the bank and makes a deposit of $1,290.00. How much money does Mr. Smith have in his savings account after 14 years if the monthly interest rate has been 0.7 %?
    A: $410,613
12. **Mr. Smith's son [4]**. John Smith, Mr. Smith's son, is really impressed with his dad's savings, and he would like to start saving for his retirement. Little John is ambitious and wants to have $1 million for his retirement within 40 years. What should be his monthly deposit at the same interest rate (0.7 %)?
    A: Modestly ~$255
13. **Loan for a friend [3]**. A friend of yours needs $1,500 and asks you for help. He promises to pay you back $2,500 in 5 years. What is the monthly interest rate on the loan?
    A: 0.855 %

12.9.2 Personal Finance

14. **To study or not to study, a simple estimation [5]**. You are finishing high school and your parents expect you to apply to The Ohio State University to pursue a bachelor's degree in chemical engineering. As Ohio State is an excellent university, and you are living in Upper Arlington, Columbus appears to be, if not the best, at least a very interesting option. Unfortunately for your parents, you are tempted to start working right away because recently you received a job offer for $30,000 a year. Your dad and mom, as professionals, are very concerned and they try to convince you to go to the university and at least get a bachelor's degree. Both mom and dad have a Ph.D. So far, they are not trying to convince you to get a Ph.D., but at least a bachelor's degree. Your dad, as an engineer, has done some calculations and demonstrates to you the advantages (in economic terms) of getting a degree. In addition, he thinks that it would be more rewarding for you as a person. For his calculation, your dad assumes that if you start working today you will work for 47 years (starting today, 47 + 18 = 65, age of retirement) and you will always receive the same salary. On the other hand, if you decide to get a bachelor's degree (4 years), instead of receiving $30,000 a year, you will spend $30,000 a year (university tuition and living). (a) What is the minimum salary with a bachelor's degree to justify getting the degree? (b) What do you think, is it worthwhile to study? Your dad assumes an annual interest rate of 10 %.
    A: (a) $58,316. (b) Although a very simple calculation, it shows us that study is not only rewarding, but also the best investment. Recalling the Benjamin Franklin quotation cited in Chap. 11: "An investment in knowledge always pays the best interest." Possibly, and rightly, you do not think that the assumption of a constant salary for 47 years is correct. Indeed, the assumption is a bad one; however, it is a terrible assumption if you get a degree. Why? Because in both cases, the salary will increase over time, but it would likely increase much more if you have a degree.

15. **To study or not to study 2, a more detailed estimation [7]**. Based on salaries in the USA, we have developed the following estimation table:

Year	Salary without bachelor's degree	Salary (cost) with bachelor's degree
0	–	–
1	$30,000	−$30,000
2	$30,000	−$30,000
3	$30,000	−$30,000
4	$30,000	−$30,000
5	$40,000 (first promotion)	$60,000
...	$40,000	$60,000
10	$40,000 (second promotion)	$60,000 − $80,000 (getting an MBA) + $100,000 (bonus) (first promotion)
11	$45,000	$90,000
...	$45,000	$90,000
20	$45,000 (third and final promotion)	$90,000 (promoted to plant manager) + $150,000 (bonus) (second promotion)
...	$50,000	$120,000
30	$50,000	$120,000 (last promotion) + $200,000 (bonus) (last promotion)
...	$50,000	$150,000
	$50,000	$150,000
47	$50,000	$150,000 + 300,000 (retirement bonus)

What is the total amount of money that you will have earned at the moment of your retirement (future value)? Assume an annual interest rate of 10 %.

A: Without a bachelor's degree, approximately $34.34 million; with a bachelor's degree and MBA, approximately $45.9 million.

12.9.3 Engineering Problems

16. **Small and medium-sized enterprises (SMEs) [6]**. An SME is investing $1.4 million to buy a new and modern machine that will increase the process efficiency. What should the monthly savings be to recover the investment in 2.5 years (NPV = 0) if the annual interest rate is 12.68 %?

    A: $54,247.40

17. **Chemical company [8]**. A chemical company that manufactures oil products buys a semiautomatic machine for $13,000. The annual maintenance cost and operation are $1,700. Five years later, the company must decide on the purchase of a unit that will fully automate the machine. The manufacturer of the unit has estimated that the company's annual maintenance cost will be reduced to $900 per year, and then 11 years later you can sell the unit for $1,800. The price of the unit is $7,100. (a) Do you recommend buying the unit? (b) If not, how much should the company pay for the unit? (c) If the cost of the unit is still $7,100, how much should the annual maintenance cost be to make buying the unit attractive? Annual interest rate = 9 %.

    A: (a) No. (b) $6,142. (c) $759

18. **Canned fish [6]**. A small food processing plant that produces canned fish wants to buy an automatic packaging machine and they are analyzing two alternatives:

	Machine A	Machine B
Price of machine ($)	150,000	250,000
Annual maintenance cost ($)	16,000	4,000
Residual value ($)	30,000	60,000
Lifespan (years)	7	10

Determine which machine should be selected using an annual interest rate of 12 %.

A: Given that the lifespans of the machines are different, one way to compare both alternatives is through the annual cost. The annual cost of machine A is $45,894, and the annual cost of machine B is $44,827. Therefore, machine B is selected.

19. **Equipment company [5]**. The Alba Equipment Company wants to buy a new machine to build heat exchangers. The expected additional revenue from the machine is $150,000 at the end of the first year, $120,000 at the end of the second year, $90,000 at the end of the third year, and so on. The company expects that the machine will not be operative after year 6; therefore, its residual value is zero. If the interest rate is 15 % per year, how much should the company be willing to pay for the machine?

A: $329,569

20. **Company expansion [6]**. A company that is planning to expand has deposits $700,000 annually for 8 years. Starting with the ninth year, the company increases the deposit to $1.2 million for 5 years. How much money does the company have in its account immediately after making the last deposit if the average interest rate for the capitalization of the funds is 5 % per year?

A: $15.162 million

21. **Old house [9]**. A builder dedicated to restoring old houses and selling them acquires a nice, big old house, but in bad condition, for $1.7 million. At the end of the first month, he has invested $300,000. Immediately after he repairs the house, a couple looking for a house offers him $2.4 million for the old and now beautifully restored house. After considering the offer, the builder decides to keep the house and rent it for $20,000 per month, receiving the first 2 months' rent after purchase. He rents the house for 15 months and then sells it for $2.2 million. If the interest rate is 1 % per month, how much extra money did the builder win or lose by not selling the house immediately after the remodeling?

A: He lost approximately $264,400 (money at month 16)

22. **High or low pressure? [8]**. A process engineer is trying to decide between two operating pressures for a waste water irrigation system. Using high pressure, the system would require less piping and sprinklers, but pumping costs would be higher. Alternatively, the process engineer can use lower pressure but more irrigators. The pumping cost is $15 psi million m^3 of wastewater. If he decides to use a pressure of 80 psi, the system will need 25 sprinklers at a cost of $220 per unit. In addition, the system will require 4,000 m of aluminum pipe at a cost of $28 per meter. A lower pressure of 50 psi would require 85 sprinklers and 13,000 m of pipe. The aluminum tubing has a lifespan of 10 years, and the sprinklers have a lifespan of 4 years. If you expect a volume of wastewater of 120 million m^3 per year: (a) What pressure should be selected? (b) What pressure should be selected if the cost of pumping increases to $20 psi*million m^3 of wastewater? (c) At what price are both pumping alternatives equivalent? The annual interest rate is 20 % per year.

A: (a) High pressure (the annual cost of high pressure is ~$172,800 and for low pressure ~ $184,046). (b) Low pressure (the annual cost of high pressure is ~$220,800 and for low pressure ~$214,046). (c) ~$18.1 psi*million m^3 of wastewater

23. **Sausage factory [10]**. A sausage factory needs a new cooling system. The company manager asks you as an engineer for your expertise in food refrigeration. You must decide between two alternatives. The spray method showers water on the hams until the temperature drops to 15 °C. This method requires L_S liters of water per ham. However, an immersion method that only requires L_I liters of water per ham ($L_I < L_S$) might be better. However, this method would require an additional initial investment of \$AI with additional repair costs of \$RC per year, and the equipment has a lifespan of 10 years. The company processes N_J million hams per year and pays $\$C_W$ per liter of cold water. The company also must pay $\$R_W$ per 1,000 [L] to remove the sewage. If the annual interest rate is 15 %, find an expression where the annual cost of each alternative is the same.
    A: $L_S \times N_J \times C_W + R_W \times L_S \times N_J/1{,}000 = L_I \times N_J \times C_W + [(AI \times 0.15 \times (1.15)^{10})/((1.15)^{10} - 1)] + RC + R_W \times L_I \times N_J/1{,}000$
24. **High-tech laboratory [10⁺]**. A highly specialized biotechnology company is considering installing a laboratory at its plant to avoid having to send samples to independent laboratories for analysis. If a full laboratory were installed, the initial investment would be \$250,000. It would require a specialized biotechnologist at a cost of \$130,000 per year. The cost of utilities, chemicals, etc. would be \$50 per sample. If the laboratory were only partially installed, the initial investment would be \$100,000 and would require a specialized biotechnologist working half time with a salary of \$50,000 a year. The cost of the sample analyzed in this laboratory would be \$30, but because not all tests can be performed in the laboratory, the services of an outside laboratory would be required at a cost of \$200 a sample. If the company prefers to continue with the current system, each sample will cost \$550. The laboratory equipment has a lifespan of 12 years and the annual interest rate is 10 %. How many samples must be analyzed each year to justify the installation of a (a) full or (a) partial laboratory in relation to the external laboratory? (c) If the company expects to analyze 175 samples per year, which of the three alternatives should be selected?
    A*: (a) >333 samples per year. (b) >202 samples per year. (c) External laboratory analysis.
    *It is necessary to add that for 333 samples or more, the complete laboratory is better than the current situation (external laboratory), but at this number of samples, the best option is the partial laboratory. In fact, from 0 to 202 samples the best option is the external laboratory, from 202 to 570 the partial laboratory, and from 570 samples, the best option is the full laboratory.
25. **High-tech laboratory 2 [9]**. In relation to the previous problem, the external laboratory, knowing that the biotech company is looking into the possibility of having its own laboratory facility, decides to lower the price of its analyses. The external laboratory does not believe that the biotech company would ever send out more than 250 samples for analysis per year, so the laboratory decides to lower its price to \$475 per sample. Analyze and discuss the price set by the external laboratory. Is it sufficient to go down to \$475 per sample?
    A: When the price per sample was \$550, the external laboratory was better than the partial laboratory as long as the number of samples was less than 202. By lowering the price to \$475, the external laboratory will be a good option as long as the number of samples is less than 263, and so it is a good move because the number of samples will not be more than 250.
26. **Sports car [9]**. The owner of a car is deciding between buying four radial tires or four retreaded tires. The radial tires cost \$200 each and would last 42,000 [miles]. The retreaded tires cost \$70 each but would last only 12,000 [miles]. Since this is a sports car, the owner uses it only on weekends, putting on 6,000 [miles/year]. Assuming that the cost of gasoline is \$1 per liter and the car consumes a gallon every 20 [km], what kind of tires should the car owner buy if the interest rate is 6 % per year?

A: As the lifespan of each kind of tire is different (7 years for the radial and just 2 years for the retreaded tires), an easy way to compare both alternatives is by calculating the annual cost of each kind of tire. The annual cost of the radial tires is $143.30 and for the retreaded tires it is $152.70. The radial tires are not only a bit cheaper per year but also safer.

27. **Canning company [7]**. A canning company wants to expand its product line, for which will it buy a new fruit grinder. An equipment manufacturer offers two options for machinery whose costs are presented in the following table:

	Machine A	Machine B
Price of machine ($)	260,000	360,000
Annual maintenance cost ($)	10,000	5,000
Annual labor cost ($)	110,000	70,000
Residual value ($)	20,000	30,000
Lifespan (years)	6	9

If both machines are equally suitable for the production line, which one should the canning company buy? Assume an annual interest rate of 10 %.

A: The annual cost for machine A is $177,105 and for machine B $135,300. Thus, it is better to buy machine B.

28. **Community center [9]**. A planning commission in Columbus, Ohio, is considering two proposals for the development of a new community center. Proposal O requires an initial investment of $12 million and a cost of expansion of $400,000 per year for 10 years. It is expected that the annual operating cost will be $250,000. In addition, the commission is expecting to receive $190,000 the first 4 years from conventions, shows, and other events and then $280,000 until the tenth year. From the 11th year onward, the income would be $350,000 per year.

Proposal H would require an initial investment of $15 million and annual operating costs of $300,000 per year. The income is expected to be $320,000 for the first 7 years. Then, the income will be $440,000 annually.

Determine which proposal the committee should select if the interest rate is 6 % per year, assuming an evaluation horizon of 20 years and a residual value for each alternative of 20 % of the initial investment.

A: The present value of proposal O is approx. −$13.87 million and the present value of proposal H is approx. −$13.1 million. Therefore, proposal H is a cheaper but not necessarily better proposal. Why? In the real world, you need to considerer other factors to make a final decision, even in cases like this, where the difference is very small and the investment is significant for the community.

29. **Storage pond [7]**. A company is buying a water storage pond at a value of $6,000. The production manager is considering the possibility of coating the pond because due to the high concentration of salts in the water, under present conditions, the pond will have an extremely short lifespan. An alternative is to apply a bituminous coating at a cost of $3,000. This would increase the lifespan to 6 years, after which, if the coating is repaired, at a cost of $500, it could last another 3 years. Another alternative would be to apply an epoxy coating, giving a lifespan of 14 years. How much money would the company need to pay for the epoxy coating so that the two alternatives were equivalent? The annual interest rate is 7 %. In addition, at the end of the pond's lifespan, its residual value would be 10 % of the initial cost.

A: ~ $6,380

30. **Chemical company [8]**. A medium-sized chemical company wants to replace an old reactor with a new one. So far they have received three offers, as follows:

Equipment	Reactor A	Reactor B	Reactor C
Price ($)	60,000	100,000	200,000
Annual labor cost ($)	21,000	12,000	5,000
Annual maintenance ($)	–	5,000	–
Maintenance every 3 years (years 3, 6, and 9)	25,000	–	–
Residual value ($)	45,000	–	100,000
Lifespan (years)	12	10	8

At a similar annual cost, the company will prefer reactor A, meaning that if reactor A is no more than $1,000/year compared to the cheapest alternative, the company will buy reactor A. If the annual interest rate is 10 %, which of the reactors will the company buy?

A: The annual cost for the three alternatives is very similar: for reactor A it is $34,085, for reactor B $33,274, and for reactor C $33,744. Therefore, although reactor A it is not the cheapest, it is the one selected according to the criteria established by the company.

31. **Instant coffee [8]**. A company that produces instant coffee needs to replace its old evaporators with new ones. The project engineers are looking at two alternatives. The first alternative has a cost of 2,200 arbitrary monetary units [MU] and retains the current plant capacity of 1,100 [kg/h] of instant coffee. The second alternative has a cost of 2,650 MU and allows for a 5 % increase in plant capacity. In addition, the evaporator of the second alternative can be sold at the end of its lifetime for 700 [MU]. In either case, the profits from selling instant coffee are 0.2 [MU/ton]. The plant operates continuously 300 days a year. Assuming an evaluation horizon of 10 years and an annual interest rate of 7 %, determine which of the two alternatives is more profitable.

A: The second alternative is better. The NPV of the first alternative is 8,925 [MU] and the NPV of the second alternative is 9,388 [MU].

32. **Canning company [6]**. A small canning company decides to apply for certification to meet international requirements, which would allow it to export 55 % of its production to international markets. This would increase the profits of the cannery. The certification process and the adjustments to be made to the plant to meet international standards have a total cost of 770.25 [MU]. How much should the cannery increase its profits per year for a payback in 4 years with an annual interest rate of 10 %?

A: 243 [MU/year]

33. **Natural sweeteners [8]**. A plant that produces natural sweeteners produces 100 [ton/year] running at full capacity, but based on a market research study the managers have been advised to increase production to 300 [ton/year]. The first alternative is to do this by increasing the plant capacity to 300 [ton/year] in one step at the start of the project, which will cost 1,000 [MU]. The second alternative is to do it in two stages, each time increasing the capacity by 100 [ton/year], one at the beginning of the project, at a cost of 600 [MU], and the other in the fifth year at a cost of 500 [MU]. Currently the annual profits are 100 [MU/year], which is directly proportional to the level of production. Determine which alternative is the best option in an evaluation horizon of 10 years and at an annual interest rate of 12 %.

A: The first alternative is better. NPV(1) = 695.1 [MU] and NPV(2) = 450.9 [MU]

34. **Shrimp waste [9]**. A fishery working with crustaceans is considering different alternatives for the disposal of waste. Currently the disposal of 11 tons per month of residual shells has a cost of 180,000 [MU]. The fishery is prepared to offer an 8-year contract for the best proposal. A manufacturer of lime is offering to pay 4,500 [MU/ton], removing the residue from the

company. Also, an innovative company that produces chitosan from crustacean shells is offering to pay 9,000 [MU/ton], but the offer does not include the removal of waste. The fishery estimates that it would have to pay 55,000 [MU] for each 11-ton freight. Since the fishery is interested in the proposal of the innovative chitosan producer, it is looking into whether the company can improve its offer. After a thorough analysis, the chitosan producer says that it can cover the costs of removing the waste from the fishery plant the first 2 years. If the annual interest rate is 12 %, determine which of the two alternatives is most attractive, i.e., the one with the larger NPV.
A: NPV(Lime) = 14,417,937 [MU] and NPV(Chitosan) = 15,247,936 [MU]

35. **Olive oil [8]**. A cooperative with many years of experience working with olives is exploring the possibility of producing olive oil. For this it has developed a project that begins with the construction of a warehouse and installation of the necessary equipment, second hand, all for a cost of 200 [MU]. This would allow it to operate for 3 years with profits of 180 [MU] per year, producing 6,000 [L] of olive oil per year. In the fourth year production is projected to increase by 2,000 [L] annually, maintaining the ratio of profits per liter of oil. For the sixth year, it is projected that the equipment originally purchased will need to be replaced at a cost of 250 [MU], which would allow an oil of better quality to be produced. The old equipment will be sold at a price of 40 [MU]. The cooperative will take advantage of this change to modify the container to a lighter volume, but this would allow the oil to be sold at higher prices on the most exclusive markets, increasing the relative utility per liter of oil by 50 %. This will increase production again to 2,000 [L/year]. Calculate the NPV of the project given an evaluation horizon of 10 years and an interest rate of 12 %.
A: 1,228.7 [MU]
36. **Biogas production [9]**. It has been estimated that the installation of a plant to produce biogas from human waste has a negative NPV of $2.8 million in an evaluation horizon of 8 years and at an annual interest rate of 6 %. To make the installation profitable, the project engineer proposes to sell dry biol as fertilizer, which requires an additional investment of $600,000 for the purchase of two thickeners, $2.2 million for the installation of dryers, and $1,000,000 for the purchase of additional land. Further, it will be necessary to hire an extra worker at a salary of $5,000 per month. This is expected to earn extra revenue of $1.96 million per year. Determine the NPV resulting from the sale of the dry biol fertilizer coupled with biogas production.
A: NPV = $5,198,608
37. **Protein purification [10]**. A certain protein is produced industrially by fermentation, which is then followed by a series of separation processes to obtain the pure protein for packaging. A new plant will be installed and two alternatives have been proposed. The first alternative has an installed cost of 25,000 [MU] and an operating cost of 0.020 [MU/L] (liters of broth fed to the process), making it possible to attain a purity of 95 %. The second alternative has an installed cost of 34,000 [MU] and an operating cost of 0.024 [MU/L], enabling a purity of 99.5 %. A certain continuous fermenter designed to produce the protein at a concentration of 15 [g/L] operates at a flow rate of 100 [L/h]. Assume that the fermenter operates continuously 330 days a year. The protein with 95 % purity is sold for 3.0 [MU/kg] and the protein with 99.5 % purity sold for 4.5 [MU/kg]. Determine which of the two alternatives is more profitable given an evaluation horizon of 10 years and an annual interest rate of 10 %.
A: NPV(1) = 96,662 [MU] and NPV(2) = 177,693 [MU]
38. **Anaerobic digester [8]**. A pig farmer is considering installing an anaerobic digester to treat the waste generated by the pigs. For this the farmer has only one alternative, which is inexpensive but has not been tested elsewhere, so its design is only theoretical and would cost $3.2 million. Estimates indicate that the availability of waste can generate 3 [m^3/day] of biogas, which can be

used to replace the use of LPG in the club nearby. The gas can be sold to the club at \$700.00/m^3, and the operating costs of the plant would be \$39,600 a year in supplies; there would be no labor costs in addition to those related to waste disposal. Since the theoretical model has not been tested, it is highly recommended to evaluate the project under different price scenarios. (a) What is the NPV of the project if the cost of biogas is \$700.00/m^3? (b) What should be the price if the NPV is 0? Use an evaluation horizon of 10 years and an annual interest rate of 8 %.
A: (a) \$1,677,558.20, (b) ~\$471.70/m^3

39. **Microbrewery [10⁺]**. A microbrewery is applying for a loan of at most \$10 million at a 10 % annual interest rate to be paid back within 7 years. The microbrewery has three projects that can be implemented together or separately.
(P1) Make improvements to the analytical laboratory, with an investment of \$1.8 million, allowing the reuse of previous batches, generating savings of \$240,000 per year. This alternative has a residual value of \$500,000 after 7 years.
(P2) Make improvements to the equipment and implement energy-efficiency measures, with an investment of \$5.5 million. The microbrewery would save an estimated \$540,000 yearly in electricity and \$720,000 in liquid gas, but this would entail extra costs of \$55,000 annually to maintain the boilers. This alternative has no residual value.
(P3) Install a new fermenter/soaker, at a cost of \$3,000,000, which could increase profits by \$1,800,000 yearly. This alternative has a residual value after 7 years of \$1,000,000.
Determine the NPV of each project. What is the optimal mix of projects? Assume an evaluation horizon of 7 years and a minimum acceptable rate of return of 10 %. Assume that the loan is paid back in equal annual payments.
A: NPV(P1) = –375,000; NPV(P2) = 366,445; NPV(P3) = 6,276,312; the optimal combination is P2 and P3.

40. **Industrial liquid waste (ILW) [8]**. A company that produces antibiotics is analyzing the possibility of treating the ILW in its own plant (the plant operates 330 days per year). Currently ILW is generated at a rate of 30 [m^3/day], and the company pays a sanitation company 0.11 [MU/m^3] to treat the waste. According to the production team, ILW generation is expected to increase to 55 [m^3/day] from year 6. The company is considering two alternatives:
(A_1) Install a plant to process 30 [m^3/day] for the first 5 years at a cost of 1,000 [MU] and then at the end of year 5 install an additional plant, also at a cost of 1,000 [MU] to expand the processing capacity to 55 [m^3/day]. The cost of operating the plant would be 0.1 [MU/m^3].
(A_2) The same as (A1), with the difference that in year 5 instead of installing an additional plant, install enzymatic reactors at a cost of 3,000 [MU], but this would reduce the generation of ILW to a third of its total.
Assuming an annual interest rate of 5 % and a 10-year evaluation horizon, what is the best alternative, A1, A2, or continuing with the sanitation company?
A: The best alternative is A_2, where NPV(A_1) = –12,227 [MU]; NPV(A_2) = –9,689 [MU]; NPV(Sanitation Company) = –11,487 [MU]

Additional Web References

Net Present Value – NPV http://www.youtube.com/watch?v=HpFjzHj2x-I
Present and Future Values http://www.i-programmer.info/ebooks/financial-functions/429-present-and-future-values.html?start=4
Present value, future value, and compounding made easy http://www.youtube.com/watch?v=VyReAhTBvOw
Net Present Value http://www.youtube.com/watch?v=zGRVVSC4UUQ
Equipment Cost http://www.mhhe.com/engcs/chemical/peters/data/

Evaluation of Industrial Projects http://www.unido.org/fileadmin/user_media/Publications/download/Manual_for_Evaluation_of_Industrial_Projects.pdf

Equipment Cost http://www.google.cl/url?sa=t&rct=j&q=&esrc=s&source=web&cd=5&ved=0CFQQFjAE&url=http%3A%2F%2Fwww.che.utah.edu%2F~ring%2FDesign%2520I%2FLecture_Ppts%2F7-L2-Equipment%2520Costing.ppt&ei=AekYUo7ZCefkiALDsoHwDg&usg=AFQjCNFive4Hz0T91WzYel31YEDY0aEbbg&sig2=zun8ucVmmvJRK36MB8SJ8Q

Cost Estimator http://highered.mcgraw-hill.com/sites/0072392665/student_view0/cost_estimator.html