operating and maintenance costs (including income taxes) initially will be $250,000 and will increase to $0.35 million after the second addition (from the 11th year to the 15th year) and to $0.45 million during the final 10 years. (Assume that these costs begin one year subsequent to the actual addition.)

On the basis of the present-worth criterion, if the firm uses 15% as a MARR, which alternative should be undertaken?

5.57 A large refinery–petrochemical complex is to manufacture caustic soda, which will use feedwater of 10,000 gallons per day. Two types of feedwater storage installation are being considered over the 40 years of their useful life.

- **Option 1.** Build a 20,000-gallon tank on a tower. The cost of installing the tank and tower is estimated to be $164,000. The salvage value is estimated to be negligible.
- **Option 2.** Place a tank of 20,000-gallon capacity on a hill, which is 150 yards away from the refinery. The cost of installing the tank on the hill, including the extra length of service lines, is estimated to be $120,000 with negligible salvage value. Because of the tank's location on the hill, an additional investment of $12,000 in pumping equipment is required. The pumping equipment is expected to have a service life of 20 years with a salvage value of $1,000 at the end of that time. The annual operating and maintenance cost (including any income tax effects) for the pumping operation is estimated at $1,000.

If the firm's MARR is known to be 12%, which option is better on the basis of the present-worth criterion?

Short Case Studies

ST5.1 Apex Corporation requires a chemical finishing process for a product under contract for a period of six years. Three options are available. Neither option 1 nor option 2 can be repeated after its process life. However, option 3 will always be available from H&H Chemical Corporation at the same cost during the period that the contract is operative. Here are the options:

- **Option 1:** Process device A, which costs $100,000, has annual operating and labor costs of $60,000 and a useful service life of four years with an estimated salvage value of $10,000.
- **Option 2:** Process device B, which costs $150,000, has annual operating and labor costs of $50,000 and a useful service life of six years with an estimated salvage value of $30,000.
- **Option 3:** Subcontract out the process at a cost of $100,000 per year.

According to the present-worth criterion, which option would you recommend at $i = 12\%$?

ST5.2 A utility company is in the process of considering two alternative methods of providing transformer capacity.

- **Option 1:** Purchase a 16 MVA transformer now and add a similar-sized unit at a later date when load growth is warranted. The price of a 16 MVA unit is $680,000.
- **Option 2:** Purchase a 25 MVA transformer at the outset which will meet the future load growth for at least the next 10 years. The price of a 25 MVA unit is $920,000.

Technical specs for the transformers are as given in Table ST5.2.

TABLE ST5.2

Descriptions	Option 1	Option 2
No-load losses	16.1 kW	21.8 kW
Full-load losses	88 kW	121 kW
Cost of the no-load losses	$680/kW	$680/kW
Cost of the full-load series losses	$280/kW	$280/kW

Suppose the expected load growth over the next 20 years is 11 MVA during the first year and 1 MVA each following year over the previous year. Each transformer has a useful life of 20 years. Which transformer unit would be selected using an interest rate of 8% with the study period of 10 years? How about with 20 years? Assume the future replacement cost would be the same as the intial purchase price.

ST5.3 Tampa Electric Company, an investor-owned electric utility serving approximately 2,000 square miles in west central Florida, was faced with providing electricity to a newly developed industrial park complex. The distribution engineering department needed to develop guidelines for the design of the distribution circuit. The "main feeder," which is the backbone of each 13-kV distribution circuit, represents a substantial investment by the company.[5]

Tampa Electric has four approved main feeder construction configurations: (1) crossarm, (2) vertical (horizontal line post), (3) vertical (standoff pin), and (4) triangular, as illustrated in Table ST5.3. The width of the easement sought depends on the planned construction configuration. If crossarm construction is planned, a 15-foot easement is sought. A 10-foot wide easement is sought for vertical and triangular configurations.

Once the required easements are obtained, the line clearance department clears any foliage that would impede the construction of the line. The clearance cost is dictated by the typical tree densities along road rights-of-way. The average cost to trim one tree is estimated at $20, and the average tree density in the service area is estimated to be 75 trees per mile. The costs of each type of construction are as given in Table ST5.3a

Additional factors to consider in selecting the best main feeder configuration are as follows. In certain sections of Tampa Electric's service territory, ospreys often nest on transmission and distribution poles. The nests reduce the structural and electrical integrity of the poles. Crossarm construction is most vulnerable to osprey nesting, since the crossarm and braces provide a secure area for construction of the nest. Vertical and triangular construction do not provide such spaces. The insulation strength of a construction configuration may favorably or adversely affect the reliability of the line for which the configuration is used. A common measure of line insulation strength is the critical flashover (CFO) voltage. The greater the CFO, the less susceptible the line is to nuisance flashovers from lightning and other electrical phenomena.

The utility's existing inventory of crossarms is used primarily for main feeder construction and maintenance. The use of another configuration for main feeder construction would result in a substantial reduction in the inventory of crossarms. The line crews complain that line spacing on vertical and triangular construction is too restrictive for safe live line work. Each accident would cost $65,000 in lost work and other medical expenses. The average cost of each flashover repair would be $3,000. Table ST5.3b lists the values of the factors involved in the four design configurations.

All configurations would last about 20 years with no salvage value. It appears that non-crossarm designs are better, but engineers need to consider other design factors, such as safety, rather than just monetary factors when implementing the project. It is true that the line spacing on triangular construction is restrictive. However, with a better clearance design between phases for vertical construction, the hazard would be minimized. In the utility industry, the typical opposition to new types of construction is caused by the confidence acquired from constructing lines in the crossarm configuration for many years. As more vertical and triangular lines are built, opposition to these configurations should decrease. Which of the four designs described in the preceding table would you recommend to the management? Assume Tampa Electric's interest rate to be 12%.

TABLE ST5.3A

Factors	Design Configurations			
	Crossarm	Triangular	Horizontal Line	Standoff
Easements	$487,000	$388,000	$388,000	$388,000
Line clearance	$613	$1,188	$1,188	$1,188
Line construction	$7,630	$7,625	$12,828	$8,812

[5] Example provided by Andrew Hanson from Tampa Electric Company.

TABLE ST5.3B

Factors	Design Configurations			
	Crossarm	Triangular	Horizontal Line	Standoff
Nesting	Severe	None	None	None
Insulation strength, CFO (kV)	387	474	476	462
Annual flashover occurrence (n)	2	1	1	1
Annual inventory savings		$4,521	$4,521	$4,521
Safety	OK	Problem	Problem	Problem

ST5.4 *Parking Meters Get Smarter —Wireless Technology Turns Old-Fashioned Coin-Operated Device into a Sophisticated Tool for Catching Scofflaws and Raising Cash* [6] Technology is taking much of the fun out of finding a place to park the car:

- In Pacific Grove, California, parking meters "know" when a car pulls out of the spot and quickly reset to zero—eliminating drivers' little joy of parking for free on someone else's quarters.
- In Montreal, when cars stay past their time limit, meters send real-time alerts to an enforcement officer's handheld device, reducing the number of people needed to monitor parking spaces—not to mention drivers' chances of getting away with violations.
- In Aspen, Colorado, wireless "in-car" meters may eliminate the need for curbside parking meters altogether: They dangle from the rearview mirror inside the car, ticking off a prepaid time.

Now, in cities from New York to Seattle, the door is open to a host of wireless technologies seeking to improve the parking meter even further. Chicago and Sacramento, California, among others, are equipping enforcement vehicles with infrared cameras capable of scanning license plates even at 30 miles an hour. Using a global positioning system, the cameras can tell which individual cars have parked too long in a two-hour parking zone. At a cost of $75,000 a camera, the system is an expensive upgrade of the old method of chalking tires and then coming back two hours later to see if the car has moved.

The camera system, supplied by Canada's Autovu Technologies, also helps identify scofflaws and stolen vehicles by linking to a database of unpaid tickets and auto thefts. Sacramento bought three cameras in August. Since then, its practice of "booting," or immobilizing, cars with a lot of unpaid tickets has increased sharply. Revenue is soaring, too. According to Howard Chan, Sacramento's parking director, Sacramento booted 189 cars and took in parking revenue of $169,000 for the fiscal year-end in June 2004; for fiscal 2005, the city booted 805 cars and took in more than $475,000.

In downtown Montreal, more than 400 "pay-by-space" meters, each covering 10 to 15 spaces, are a twist on regular multispace meters. Motorists park, go to the meter to type in the parking-space number, and pay by card or coin. These meters, which cost about $9,000 each, identify violators in real-time for enforcement officers carrying handheld devices: A likeness of the block emerges on the screen, and cars parked illegally show up in red.

Parking czars in municipalities across the country are starting to realize parking meters' original goals: generating revenue and creating a continuous turnover of parking spaces on city streets. Clearly, their main question is "Would there be enough new revenues from installing the expensive parking monitoring devices?" or "How many devices could be installed to maximize the revenue streams?" From the device manufacturer's point of view, the question is "Would there be enough demand for their products to justify the investment required in new facilities and marketing?" If the manufacturer decides to go ahead and market the products, but the actual demand is far less than its forecast or the adoption of the technology is too slow, what would be the potential financial risk?

[6] Christopher Conkey, staff reporter of *The Wall Street Journal*, June 30, 2005, p. B1.