# CHAPTER 3

# **Cost-Estimation Techniques**

- Whenever an engineering economic analysis is performed for a major capital investment, the cost-estimating effort for that analysis should be an integral part of a comprehensive planning and design process requiring the active participation of not only engineering designers but also personnel from marketing, manufacturing, finance, and top management.

- Results of cost estimating are used for a variety of purposes, including the following:
**1.** Providing information used in setting a selling price for quoting, bidding, or evaluating contracts
**2.** Determining whether a proposed product can be made and distributed at a profit (for simplicity, price = cost + profit)
**3.** Evaluating how much capital can be justified for process changes or other improvements
**4.** Establishing benchmarks for productivity improvement programs

# Approaches for Cost Estimating

- There are two fundamental approaches to cost estimating: the "top-down" approach and the "bottom-up" approach.
- The top-down approach basically uses historical data from similar engineering projects to estimate the costs, revenues, and other data for the current project by modifying these data for changes.
- This approach is best used early in the estimating process when alternatives are still being developed and refined.

- The bottom-up approach is a more detailed method of cost estimating. This method breaks down a project into small, manageable units and estimates their economic consequences.
- These smaller unit costs are added together with other types of costs to obtain an overall cost estimate.
- This approach usually works bet  when the detail concerning the desired output (a product or a service) has been defined and clarified.

**EXAMPLE 3-1** **Estimating the Cost of a College Degree**

A simple example of cost estimating is to forecast the expense of getting a Bachelor of Science (B.S.) from the university you are attending. In our solution, we outline the two basic approaches just discussed for estimating these costs.

### Solution

A top-down approach would take the published cost of a four-year degree at the same (or a similar) university and adjust it for inflation and extraordinary items that an incoming student might encounter, such as fraternity/sorority membership, scholarships, and tutoring. For example, suppose that the published cost of attending your university is \$15,750 for the current year. This figure is anticipated to increase at the rate of 6% per year and includes full-time tuition and fees, university housing, and a weekly meal plan. Not included are the costs of books, supplies, and other personal expenses. For our initial estimate, these "other" expenses are assumed to remain constant at \$5,000 per year.

The total estimated cost for four years can now be computed. We simply need to adjust the published cost for inflation each year and add in the cost of "other" expenses.

| Year | Tuition, Fees, Room and Board | "Other" Expenses | Total Estimated Cost for Year |
|---|---|---|---|
| 1 | \$15,750 × 1.06 = \$16,695 | \$5,000 | \$21,695 |
| 2 | 16,695 × 1.06 = 17,697 | 5,000 | 22,697 |
| 3 | 17,697 × 1.06 = 18,759 | 5,000 | 23,759 |
| 4 | 18,759 × 1.06 = 19,885 | 5,000 | 24,885 |
| | | Grand Total | \$93,036 |

In contrast with the top-down approach, a bottom-up approach to the same cost estimate would be to first break down anticipated expenses into the typical categories shown in Figure 3-1 for each of the four years at the university. Tuition and fees can be estimated fairly accurately in each year, as can books and supplies. For example, suppose that the average cost of a college textbook is \$100. You can estimate your annual textbook cost by simply multiplying the average cost per book by the number of courses you plan to take. Assume that you plan on taking five courses each semester during the first year. Your estimated textbook costs would be

$$\left(\frac{5\text{ courses}}{\text{semester}}\right)(2\text{ semesters})\left(\frac{1\text{ book}}{\text{course}}\right)\left(\frac{\$100}{\text{book}}\right) = \$1{,}000.$$

The other two categories, living expenses and transportation, are probably more dependent on your lifestyle. For example, whether you own and operate an automobile and live in a "high-end" apartment off-campus can dramatically affect the estimated expenses during your college years.

# The Internet

- can also be a source of cost-estimating data, though you should assure yourself that the information is from a reputable source.
- The following Web sites may be useful to you both professionally and personally.

| | | |
|---|---|---|
| www.enr.com | *Engineering News-Record* | Construction and labor costs |
| www.kbb.com | Kelley Blue Book | Automobile pricing |
| www.factsonfuel.com | American Petroleum Institute | Fuel costs |

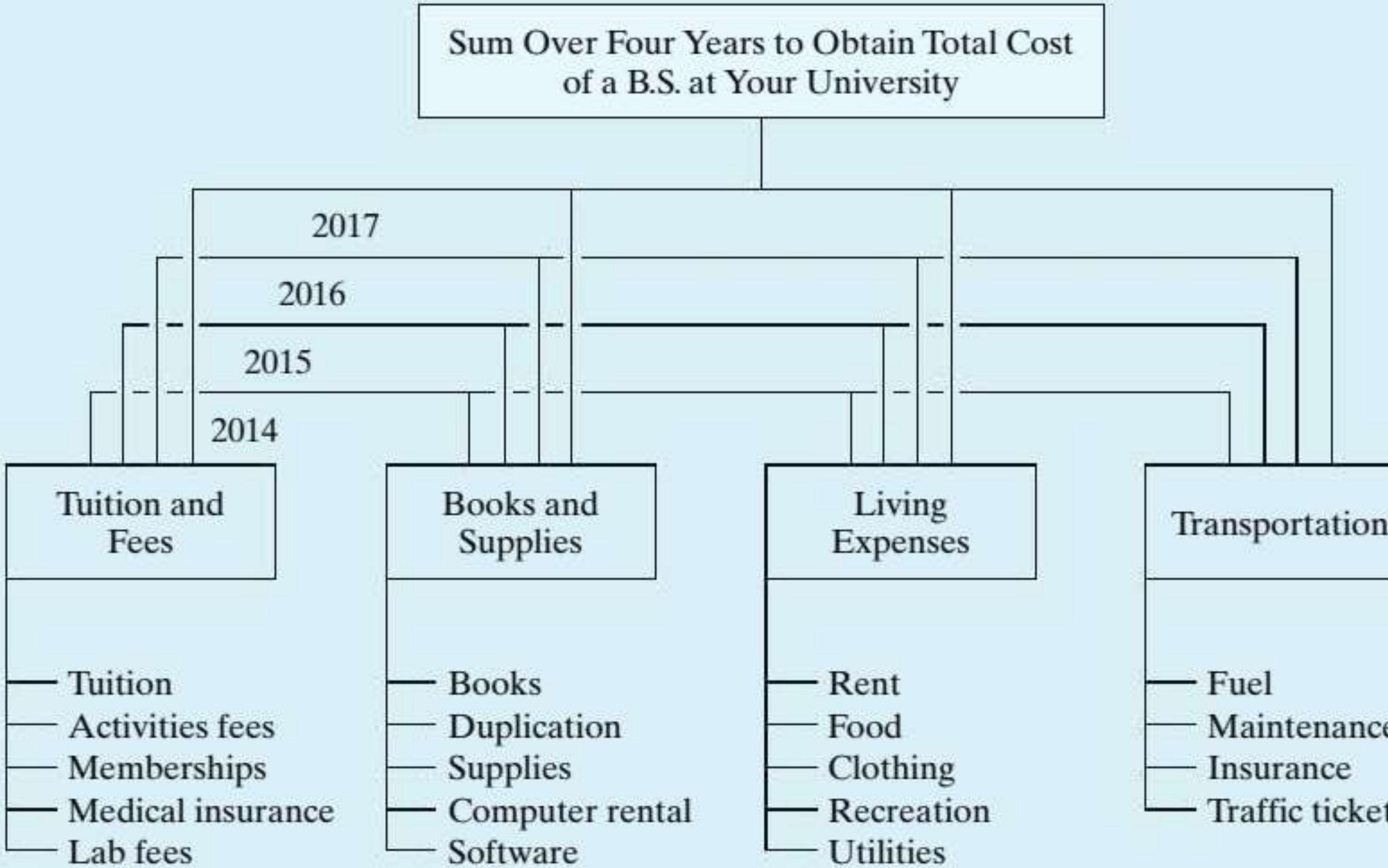


**Figure 3-1** Bottom-Up Approach to Determining the Cost of a College Education

# An Integrated Approach

- An integrated approach to developing the net cash flows for feasible project alternatives is shown in Figure .
- This integrated approach includes three basic components:
  **1. *Work breakdown structure (WBS) :***This is a technique for explicitly defining, at successive levels of detail, the work elements of a project and their interrelationships (sometimes called a *work element structure*).
  **2. *Cost and revenue structure(classification) :***Delineation of the cost and revenue categories and elements is made for estimates of cash flows at each level of the WBS.
  **3. *Estimating techniques (models) :***Selected mathematical models are used to estimate the future costs and revenues during the analysis period.
- These three basic components, together with integrating procedural steps, provide an organized approach for developing the cash flows for the alternatives.

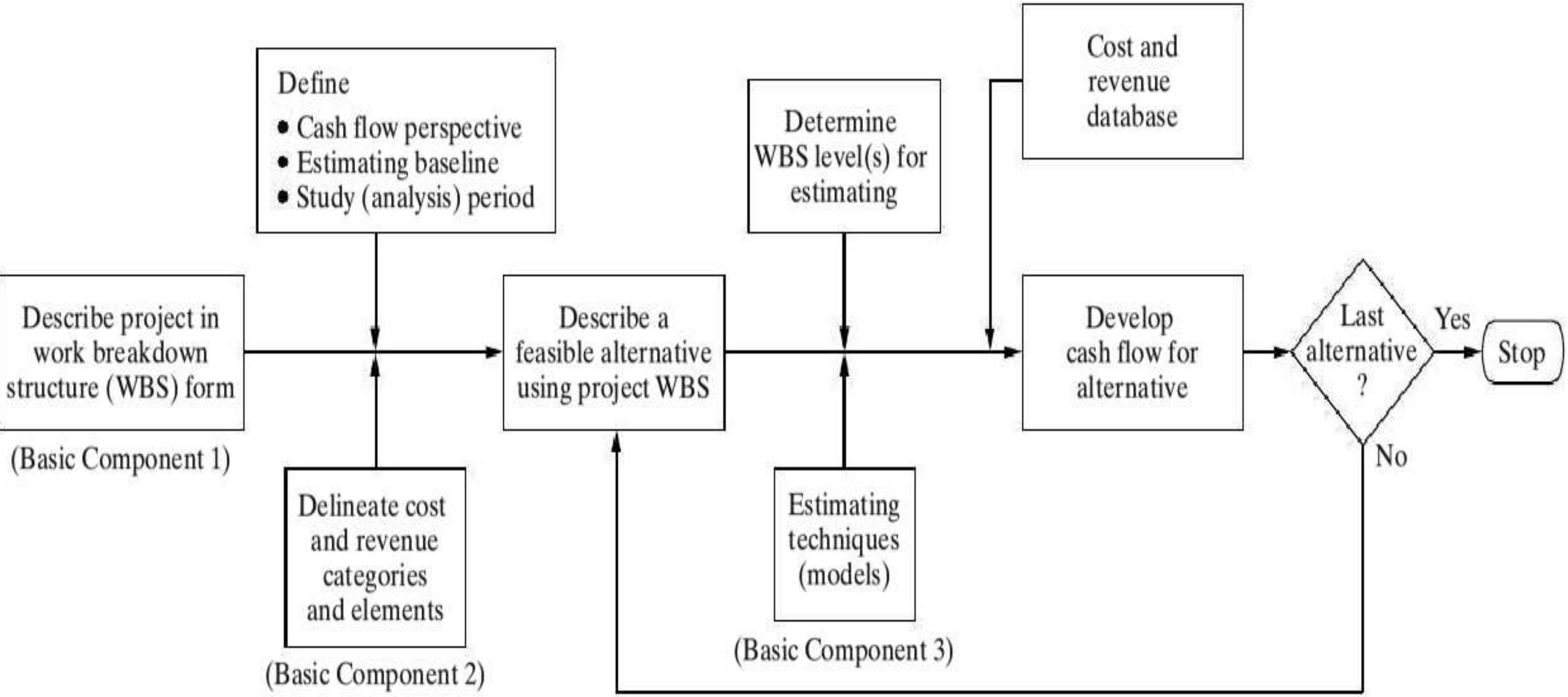


**Figure 3-2** Integrated Approach for Developing the Cash Flows for Alternatives

- As shown in Figure , the integrated approach begins with a description of the project in terms of a WBS. WBS is used to describe the project and each alternative’s unique characteristics in terms of design, labor, material requirements,and so on.
- Then these variations in design, resource requirements, and other characteristics are reflected in the estimated future costs and revenues (net cash flow) for that alternative.
- To estimate future costs and revenues for an alternative, the perspective (viewpoint) of the cash flow must be established and an estimating baseline and analysis period defined.

- Normally, cash flows are developed from the owner’s viewpoint. **The net cash flow for an alternative represents what is estimated to happen to future revenues and costs from the perspective being used.**
- Therefore, the estimated changes in revenues and costs associated with an alternative have to be relative to a baseline that is consistently used for all the alternatives being compared.

# The Work Breakdown Structure (WBS)

- The first basic component in an integrated approach to developing cash flows is the work breakdown structure (WBS).
- The WBS is a basic tool in project management and is a vital aid in an engineering economy study.
- The WBS serves as a framework for defining all project work elements and their interrelationships,
  collecting and organizing information, developing relevant cost and revenue data, and integrating project management activities.
- Figure shows a diagram of a typical four-level WBS. It is developed from the top (project level) down in successive levels of detail. The project is divided into its major work elements (Level 2).
- These major elements are then divided to develop Level 3, and so on. For example, an automobile (first level of the WBS) can be divided into second-level components (or work elements) such as the chassis, drive train, and electrical system.
- Then each second-level component of the WBS can be subdivided further into third-level elements. This process is continued until the desired detail in the definition and description of the project or system is achieved.

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  Different **numbering schemes** may be used.
- The objectives of numbering are to indicate the interrelationships of the work elements in the hierarchy.
- The scheme illustrated in Figure is an alphanumeric format.
- Another scheme often used is all numeric—Level 1: 1-0; Level 2: 1-1, 1-2, 1-3; Level 3: 1-1-1, 1-1-2, 1-2-1, 1-2-2, 1-3-1, 1-3-2; and so on (i.e., similar to the organization of this book)..

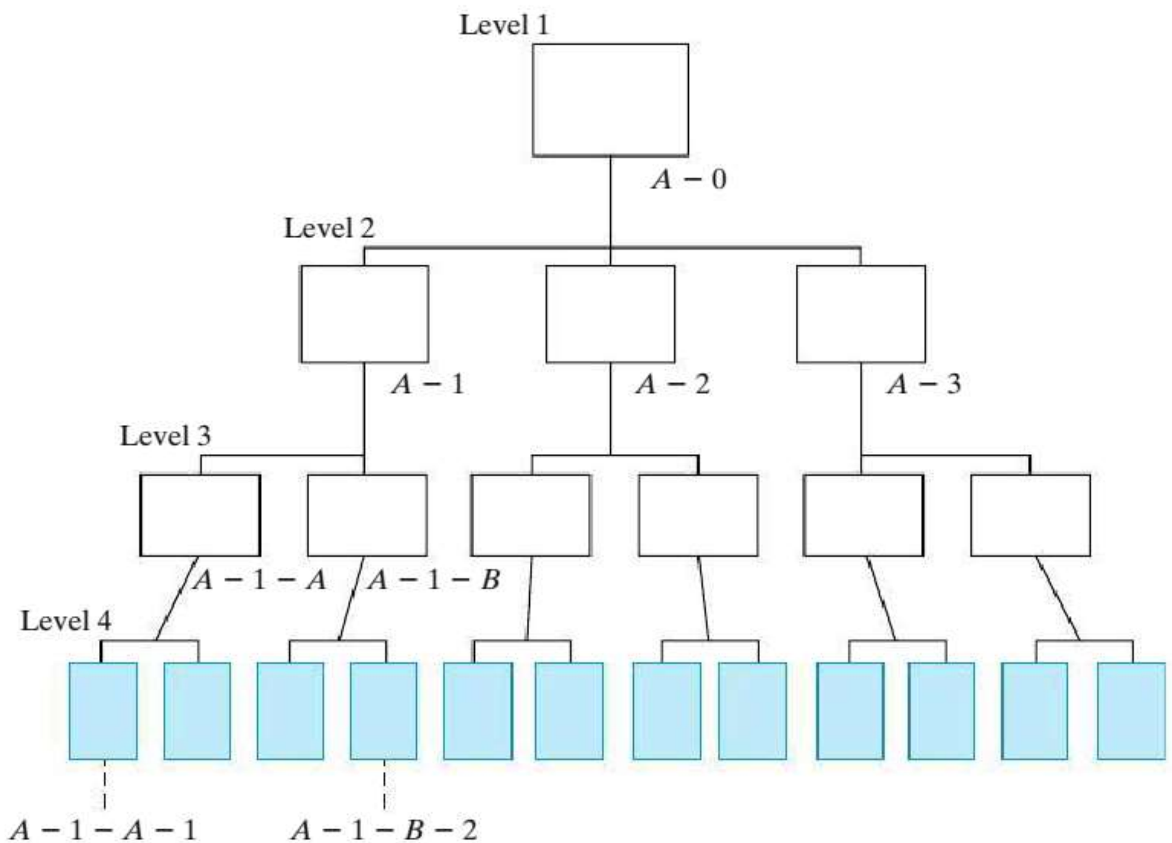


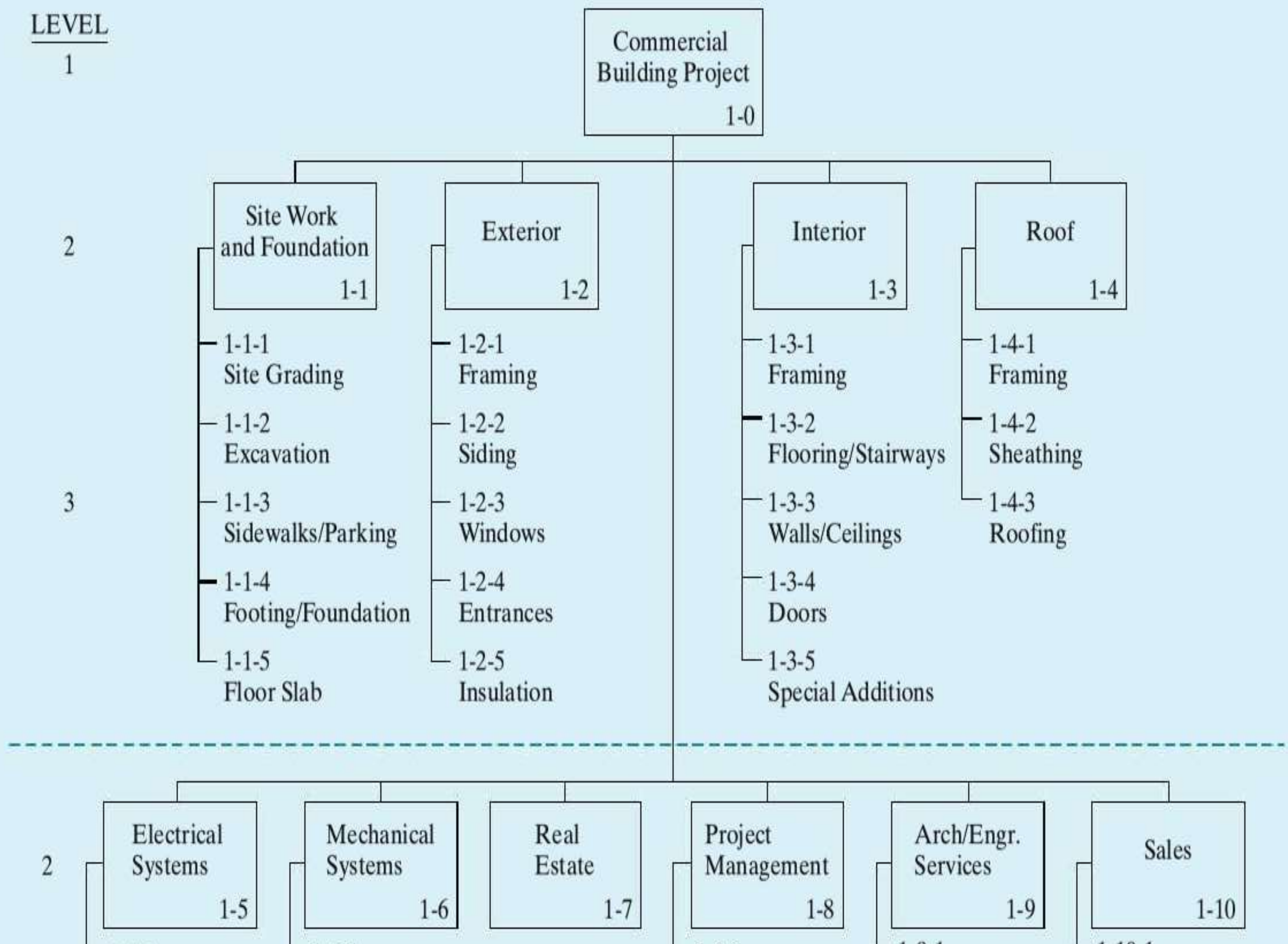

**Figure 3-3** The WBS Diagram

## EXAMPLE 3-2 A WBS for a Construction Project

You have been appointed by your company to manage a project involving construction of a small commercial building with two floors of 15,000 gross square feet each. The ground floor is planned for small retail shops, and the second floor is planned for offices. Develop the first three levels of a representative WBS adequate for all project efforts from the time the decision was made to proceed with the design and construction of the building until initial occupancy is completed.

### Solution

There would be variations in the WBSs developed by different individuals for a commercial building. A representative three-level WBS is shown in Figure 3-4. Level 1 is the total project. At Level 2, the project is divided into seven major physical work elements and three major functional work elements. Then each of these major elements is divided into subelements as required (Level 3). The numbering scheme used in this example is all numeric.



LEVEL
1
2
3
2
Commercial Building Project 1-0
Site Work and Foundation 1-1
1-1-1 Site Grading
1-1-2 Excavation
1-1-3 Sidewalks/Parking
1-1-4 Footing/Foundation
1-1-5 Floor Slab
Exterior 1-2
1-2-1 Framing
1-2-2 Siding
1-2-3 Windows
1-2-4 Entrances
1-2-5 Insulation
Interior 1-3
1-3-1 Framing
1-3-2 Flooring/Stairways
1-3-3 Walls/Ceilings
1-3-4 Doors
1-3-5 Special Additions
Roof 1-4
1-4-1 Framing
1-4-2 Sheathing
1-4-3 Roofing
Electrical Systems 1-5
Mechanical Systems 1-6
Real Estate 1-7
Project Management 1-8
Arch/Engr. Services 1-9
Sales 1-10

# Estimating Techniques (Models)

- The third basic component of the integrated approach involves estimating techniques (models).
- These techniques, together with the detailed cost and revenue data, are used to develop individual cash-flow estimates and the overall net cash flow for each alternative.

# Indexes

- Costs and prices vary with time for a number of reasons, including
  (1) technological advances,
  (2) availability of labor and materials
  (3) inflation.
- An ***index*** is a dimensionless number that indicates how a cost or a price has changed with time (typically escalated) with respect to a base year.
- Indexes provide a convenient means for developing present and future cost and price estimates from historical data.

# INDEX

Statistical device which summarizes a collection of data(usually related to the price or quantity of a 'basket' of goods and services) in a single base figure.

This composite figure serves as a benchmark for measuring changes in the price or quantity data over a period (month, quarter, year).

Usually, the base is assigned an arbitrary value of 100 and all subsequent data is expressed in relation to this base.

For example, the consumer price index (CPI) of a year might stand at 95 (to indicate a fall of 5 percent in the prices) or 105 (to indicate an increase of 5 percent in the prices).

- An estimate of the cost or selling price of an item in year *n* can be obtained by multiplying the cost or price of the item at an earlier point in time (year *k*) by the ratio of the index value in year *n* $(\bar{I}_n)$ to the index value in year *k* $(\bar{I}_k)$.
- $$C_n = C_k \left( \frac{\bar{I}_n}{\bar{I}_k} \right)$$

where $k$ = reference year (e.g., 2000) for which cost or price of item is known;

$n$ = year for which cost or price is to be estimated ($n > k$);

$C_n$ = estimated cost or price of item in year $n$;

$C_k$ = cost or price of item in reference year $k$.

- This Equation is sometimes referred to as **the *ratio technique*** of updating costs and prices.
- Use of this technique allows the cost or potential selling price of an item to be taken from historical data with a specified base year and updated with an index.
- This concept can be applied at the lower levels of a WBS to estimate the cost of equipment, materials, and labor,
- as well as at the top level of a WBS to estimate the total project cost of a new facility, bridge, and so on.

## EXAMPLE 3-3 Indexing the Cost of a New Boiler

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A certain index for the cost of purchasing and installing utility boilers is keyed to 1988, where its baseline value was arbitrarily set at 100. Company XYZ installed a 50,000-lb/hour boiler for $525,000 in 2000 when the index had a value of 468. This same company must install another boiler of the same size in 2014. The index in 2014 is 542. What is the approximate cost of the new boiler?

### Solution

In this example, $n$ is 2014 and $k$ is 2000. From Equation (3-1), an approximate cost of the boiler in 2014 is

$$C_{2014} = \$525{,}000(542/468) = \$608{,}013.$$

# Power-Sizing Technique

- The *power-sizing technique*, which is sometimes referred to as an ***exponential model*** is frequently used for developing capital investment estimates for industrial plants and equipment.
- This technique recognizes that cost varies as some power of the change in capacity or size.
- That is,

$$\frac{C_A}{C_B} = \left(\frac{S_A}{S_B}\right)^X,$$

$$C_A = C_B\left(\frac{S_A}{S_B}\right)^X,$$

where $C_A$ = cost for plant A, $C_B$ = cost for plant B (both in $ as of the point in time for which the estimate is desired);

$S_A$ = size of plant A, $S_B$ = size of plant B (both in same physical units);

$X$ = *cost-capacity factor* to reflect economies of scale.*

- The value of the cost-capacity factor will depend on the type of plant or equipment being estimated.
- For example, $X$ = 0.68 for nuclear generating plants and 0.79 for fossil-fuel generating plants.

## EXAMPLE 3-6 Power-Sizing Model for Cost Estimating

VIDEO SOLUTIONS

Suppose that an aircraft manufacturer desires to make a preliminary estimate of the cost of building a 600-MW fossil-fuel plant for the assembly of its new long-distance aircraft. It is known that a 200-MW plant cost $100 million 20 years ago when the approximate cost index was 400, and that cost index is now 1,200. The cost-capacity factor for a fossil-fuel power plant is 0.79.

### Solution

Before using the power-sizing model to estimate the cost of the 600-MW plant ($C_A$), we must first use the cost index information to update the known cost of the 200-MW plant 20 years ago to a current cost. Using Equation (3-1), we find that the current cost of a 200-MW plant is

$$C_B = \$100 \text{ million} \left(\frac{1{,}200}{400}\right) = \$300 \text{ million}.$$

So, using Equation (3-4), we obtain the following estimate for the 600-MW plant:

$$C_A = \$300 \text{ million} \left(\frac{600\text{-MW}}{200\text{-MW}}\right)^{0.79}$$

$$C_A = \$300 \text{ million} \times 2.38 = \$714 \text{ million}.$$

# Sources of Estimating Data

- The information sources useful in cost and revenue estimating are too numerous to list completely.
- The following four major sources of information are listed roughly in order of importance
- 1. Accounting records.
  2.Other sources within the firm.
  3.Sources outside the firm
  4.Research and development (R&D)
  5.The Internet

# *Accounting records*

- Accounting records are a prime source of information for economic analysis.
- accounting consists of a series of procedures for keeping a detailed record of monetary transactions between established categories of assets.
- Accounting records are a good source of historical data

# *Other sources within the firm*

- The typical firm has a number of people and records that may be excellent sources of estimating information.
- Examples of functions within firms that keep records useful to economic analyses are engineering, sales, production, quality, purchasing, and personnel.

# ***Sources outside the firm***

- There are numerous sources outside the firm that can provide helpful information.
- The main problem is in determining those that are most beneficial for particular needs.
- The following is a listing of some commonly used outside sources:

# (a) *Published information*

- Technical directories, buyer indexes, U.S. government publications, reference books, and trade journals offer a wealth of information.
- For instance, *Standard and Poor's Industry Surveys* gives monthly information regarding key industries.

# (b) *Personal contacts*

- are excellent potential sources. Vendors, salespeople, professional acquaintances, customers, banks, government agencies, chambers of commerce, and even competitors are often willing to furnish needed information on the basis of a serious and tactful request.

# *Research and development (R&D)*

- If the information is not published and cannot be obtained by consulting someone, the only alternative may be to undertake R&D to generate it. Classic examples are developing a pilot plant and undertaking a test market program.

# The Internet

- can also be a source of cost-estimating data, though you should assure yourself that the information is from a reputable source.
- The following Web sites may be useful to you both professionally and personally.

| | | |
|---|---|---|
| www.enr.com | *Engineering News-Record* | Construction and labor costs |
| www.kbb.com | Kelley Blue Book | Automobile pricing |
| www.factsonfuel.com | American Petroleum Institute | Fuel costs |