4 Cost Analysis

4.1 Introduction

4.1.1 Historical Background

Engineering economics can be defined as the art and science of getting the most for your money.

One of the first books on engineering economics was, The Economic Theory of Railway Location by Arthur M. Wellington. This pioneer, who published his first edition in 1877, was appalled that the railway engineers apparently disregarded the influence of their locations upon the prospective costs and revenues of their railways. He complained, "there is no field of professional labor in which a limited amount of modest incompetence at $150 per month can set so many picks-and-shovels and locomotives at work to no purpose whatever." This serious condemnation indicates that the planners didn't really plan. They didn't plan so that operating costs would be minimized and revenues maximized.

Such concern finally led Wellington to state a classic definition of engineering:

> "Engineering is the art of doing well for one dollar what any bungler can do for two."

This rather trite definition should stimulate our thinking so that we are continually conscious of costs in any engineering design situation.

Nearly all engineering problems involve economic considerations and cost comparisons. Wellington's classic remark was his way of emphasizing this fact. In most design situations the costs which should be compared are not immediate ones but rather long range ones. That is, overall or life cycle costs for different approaches should be compared. An analytical designer will be more immediately concerned with the initial costs of producing a machine rather than the life cycle costs. However, it should be kept in mind that operating costs, maintenance costs, product liability costs, cost of capital (interest lost), etc., as well as initial costs, will in the long run decide the fiscal success of the product.

In our free enterprise system, in the long-run, a design engineer's career and salary will depend on whether the engineer's company is able to realize a profit. The engineer's accurate estimation of costs will help predict whether a profit is possible. The engineer's sound decisions, based in part on costs, are vital to profitable production.

4.1.2 A Basic Principle of Cost Analysis

In a new design situation one has to choose the "best" approach from a number of alternate approaches. This selection process is based upon selected design criteria which include both performance and cost factors. Quite obviously, the "best" approach from a cost viewpoint is based upon cost comparisons among the various candidate approaches. To act on this simple principle is generally difficult, primarily because the true best approach may elude the designer. The above comments are more pertinent to the conceptual designer than the analytical designer. The analytical designer is concerned with optimizing the system after the "best" approach has been selected. Therefore, the cost studies are directed more toward the selection of components to yield an optimum system. To avoid the omission of an alternate way which is really better than those considered, the design engineer should make a serious study of all available literature and should establish dialogues with experts in the various areas related to the design situation.

4.1.3 The Time Value of Money

Economics almost always enters into engineering decisions. In many cases, cost is the major determining factor. The time value of money cannot be neglected in determining the total cost of venturing into a new project, particularly when comparing alternative methods of accomplishing the task. The following example is adapted from Brown.

The basic problem can be illustrated by an example. An existing company has decided to manufacture a new product. A market study has produced estimates of sales volume, prices, etc. However, the method of manufacture has not yet been settled although all the possibilities except two have been eliminated for a variety of reasons. Regardless of how the product is made, its sale is expected to bring in an average of $200,000 per year. Furthermore, costs involved in sales, distribution, raw materials, etc. are expected to average $85,000 per year."

"One of the methods of manufacture (call it method A) uses semi-automatic machines. The additional yearly expenses for labor, maintenance, power (the "out-of-pocket" expenses) are $50,000. The machines will cost $250,000 to buy and install and are expected to last 10 years (and be practically worthless after that time.)"

"The other method (method B) uses an automatic machine which is more expensive to buy($400,000 initial cost and 10 year life) but which cuts "out-of-pocket" expenses to $30,000 per year."

Suppose we analyze the two methods, looking at an average year:

Method A

Gross income from sale of product	$200,000
Sales, distribution, material, etc.	$85,000
Labor, maintenance, power, etc.	$50,000
Depreciation (The machines cost a total of $250,000 and are "used up" over a 10 year period. This averages to $25,000 per year)	$25,000
Total annual cost	$160,000
Profit (Income - Cost)	$40,000

Method B

Gross income from sale of product	$200,000
Sales, distribution, materials, etc.	$85,000
Labor, maintenance, power, etc.	$30,000
Depreciation (one tenth of $400,000)	$40,000
Total annual cost	$155,000
Profit (Income - Cost)	$45,000

"So you might conclude that, if all the estimates are correct, the company will make $5,000 more profit per year by adopting method B. NOT SO! One very important item has been overlooked. To adopt method A an investment of $250,000 is required to purchase the machines: to adopt B requires and investment of $400,000. This is a very much different kind of expenditure than, for example, wages to labor. Wages are paid on a weekly basis. To a major extent they are paid out of current income (coming in from the sale of product). But the expenditure to buy manufacturing machinery must come before any products have been made. The company must already have the necessary capital."

"Now, if the company is considering method B, it must have the necessary $400,000 If it adopts B, the entire amount is invested and the $45,000 profit is the profit from that investment. On the other hand, if method A is adopted, only $250,000 need be invested in machinery. What will be done with the remaining $150,000? It could be left in a checking account, buried in a tin can, or hidden in a mattress. In none of those places, however, will it be working and there are many places where it can be invested to earn more money. Suppose the company knows a place where 8% interest on investment can be earned. If method A is adopted only $250,000 is required for machines. The remaining $150,000 can be invested at 8% and earn $12,000 per year. So with method A, the $250,000 invested in machinery earns a profit of $40,000 and the $150,000 invested elsewhere earns $12,000, a total of $52,000 from the investment of $400,000. By contrast, method B earns only $45,000 from the investment of $400,000."

"The important conclusion from all this is that money can earn money and the question to be asked about any investment is not merely 'Will it earn a profit?' but rather 'Will it earn a bigger profit here or somewhere else?'"

"In a problem of this sort, in which it has already been decided that one of a group of alternatives will be used, and in which some items are the same for all alternatives, it is possible to simplify the arithmetic considerably. Set up a table which includes only costs which differ in different alternatives and include an interest on investment term as if it were a cost."

"Thus:

	Method A	Method B
Out-of-Pocket expenses	$50,000	$30,000

Depreciation ($250,000/10) =	$25,000	(400,000/10) =	$40,000
Interest (8% x $250,000) =	$20,000	(8% x 400,000) =	$32,000
Total Cost	$95,000		$102,000

Thus, you will make $7,000 more profit ($102,000 - $95,000) on total investment by method A."

4.1.4 The Importance of Profit

According to John H. Batten, former president of Twin Disc Inc., Racine, Wisconsin, profits and jobs are inseparable. He says, "There are those outside of the business community - both in academia and the general public - who historically have exhibited a distorted view of the essential role of profit. A major public opinion poll showed that about 20% of the U.S. Population believes that business is cheating them ... and that a majority of the public thinks that business could increase wages of 10% without raising prices."

"There is a false impression that profits have increased in proportion with increased sales figures. This is not true. In fact, most American corporations lack the retained earnings (profits) or access to new and additional risk capital sufficient to maintain their position in world industry. While demand continues to mount, the means of plant expansion are less and less available."

"Business must go it alone in convincing the public that profits are healthy and vital. Profits build factories and buy machine tools. Profits support the cost of Research and Development. Profits perpetuate the economic cycle that had given Americans better educations, more leisure time and a higher standard of living than any other country in the history of the world."

"Profits are not too high. Profits are too low. They must be increased by reducing costs, increasing productivity and permitting companies to establish and charge a price that permits a fair and reasonable return on investment. Only profitable companies are able to grow, increase employment, and pay wages and dividends. Profit is the food by which a company lives. Take away that food and everyone suffers."

4.2 Cost Analysis Activities in Analytical Design and in Conceptual Design

It is of interest to make a comparison of the cost analysis activities of the analytical designer and the conceptual designer. In analytical design the type-or-system has been specified by others, usually by a manager or a conceptual designer. Consequently, analytical designers are not concerned with the general problem of whether the project is feasible and economically attractive, but rather they are concerned: first, with detail costs, second, with the initial cost of the system, and third, to some extent, with overall or life cycle costs.

The first financial task, in some instances, is to compute an estimated selling price (SP), where SP is initial cost (IC) plus profit (P). That is,

$$SP = IC + P. \quad (1)$$

Briefly, the initial cost of any new machine or device is a composite consisting of labor costs, overhead on labor, material costs and overhead on material cost of purchased parts, plus amortization costs of all tooling, plus all engineering and development costs, plus a large number of miscellaneous overhead items.

The second financial task might be to estimate the overall cost (OVC) to the buyer of the product, where

$$OVC = SP + OC. \quad (2)$$

In this relationship the operating costs (OC) would include a number of items such as power costs, maintenance costs, etc. In some organizations, for example in the automotive companies, the selling price (SP) would also include warranty costs. Furthermore, as worldwide competition between nations increases, overall costs or life cycle costs will probably be of increasing interest to analytical designers and their managers. In some industries, the costs of product liability insurance, or of defending court actions and paying settlements, is also a substantial element of product cost. Some companies supplying weapon systems to the Department of Defense (DOD) are being asked to quote the life cycle cost of their system.

In order to effectively accomplish these tasks the analytical designer will have to carefully consider all of the financial ramifications of his decisions. Furthermore, the final design should reflect a careful consideration of warranty costs, because more-and-more the burden of unusual repair costs are being assumed for some specified warranty period by the original manufacturer of the equipment.

The analytical designer, usually, can assume that the project is already funded. This means that the capital for the design and construction of a least one prototype has been allocated by management.

The analytical designer will be concerned with decisions which will affect the initial cost and the operating costs of the system they are designing. The are concerned with making optimum economic choices in the following areas:

1. the materials for new parts
2. the method of manufacture of new parts
3. the types of fastening methods and finishing methods
4. the selection of purchased components.

This is an incomplete list. There are a myriad of detail decisions to be made in the design or selection of components for a system. An analytical designer should seek out assistance from various sources, particularly those in their own organization. Such sources as production personnel, cost accountants, tool and planning experts, value analysts, and others, can give valuable assistance in cost estimating activities.

Quite obviously, the analytical designer would attempt to incorporate into the system those components, which will result in maximizing the ratio of effectiveness to cost. Here, effectiveness is the ability of a component or a system to perform its intended function when it is operating in accordance with the original design concept, that is, the loads and the environment are not different from those for which the device or machine was intended. For example, assume that a device is required which will convert rotary motion to rectilinear motion. The "black-box" for the component is represented in Figure 4.1.

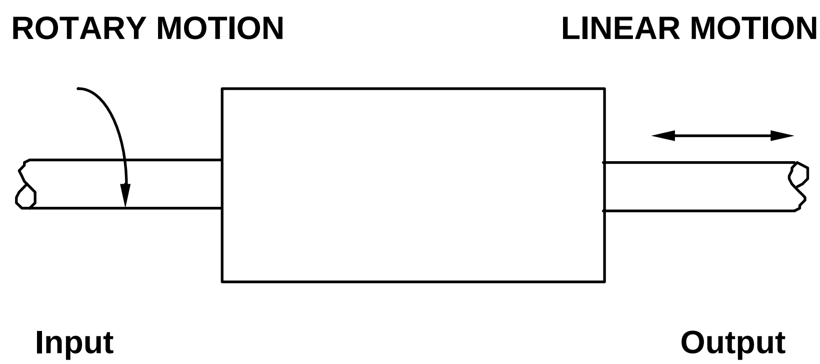

Figure 4.1: Motion Conversion Component

A partial list of the various mechanisms, which could perform this function would include:

1. Cam-and-follower
2. Rack-and-pinion
3. Power screw (or ballscrew)
4. Slider-crank

Which one of these approaches is finally selected would depend first, upon a comparison between the design requirements (or required application characteristics) and the performance characteristics of each mechanism. Such an initial comparison might eliminate some of the alternates from the list. However, the final choice would be made on the basis of comparing the magnitudes of their respective effectiveness to cost ratios. Perhaps the ratio of mechanical efficiency to cost, or life to cost, or a more complex index, such as power per pound per dollar might be used. Here effectiveness is some measure of performance and cost includes the original acquisition cost plus the maintenance cost. At this point the cost factor might have an overriding effect on the final choice, particularly if some of the alternatives have about the same performance characteristics.

The conceptual designer would, together with management, take a broader view of the costs involved in undertaking a particular project. They would apply economic principles and fiscal techniques to estimate the value of venturing into a new project. They would, in general, be concerned with the recovery of investment and the realization of a reasonable profit. To this end they would be concerned with some of the following facets of project economics:

1. the time value of money
2. tax accounting methods
3. depreciation methods
4. sinking fund analyses
5. percent rate-of-return on investment

This is not a complete list of topics pertinent to cost analysis as practiced by the conceptual designer, but it is included here only to give some insight into their activities. Also, conceptual designers would have considerable interest in life cycle costs.

4.3 Cost-Saving Activities in Analytical Design

4.3.1 Development of Cost-Awareness

Analytical designers would attempt to make their decisions on the basis of obtaining the most performance for the least amount of dollars. However, they would also keep in mind that it is in the long-run best interest of their company to give value to the customer at a fair price. Their designs would incorporate reasonable safeguards to minimize risks to the consumer. The latter would help reduce product liability costs for their company. They would develop cost-awareness in all facets of their design activities and thus assist their organization in realizing a profit. They would recognize the trend that the cost of a component or system is now being estimated by engineers during the early stages of the design process.

4.3.2 A Few Areas to Investigate for Possible Cost-Savings

The following is just a partial list of the areas which the analytical designer could investigate for possible cost savings:

1. the selection of materials
2. the choice of fits, limits, and tolerances - tight tolerances and close fits are expensive. Generally costs increase rapidly as the degree of precision is increased.
3. the selection of plain bearings versus anti friction bearings - often anti-friction bearings are used for low-volume productions while plain bearings are very inexpensive in high volume production.
4. the quality of insulation used to reduce noise.
5. the type and amount of thermal insulation utilized, and the associated size of pipe or duct employed - here designs can be readily optimized with respect to cost and effectiveness.
6. the degree of precision or quality of a purchased part - a common example is the replacement of a low-class (low precision) ball-bearing with an equivalent high-class ball bearing. Here a significant increase in life (effectiveness) can be

realized but only with a significant initial cost penalty. We have traded-off initial cost for performance, and the effectiveness-to-cost ratio may increase or decrease depending on whether the cost factor reflects the total cost.

7. the quality of surface finish employed can have a significant effect on cost. If hand finishing is required the added cost is notoriously large, but a high grade finish can have a significant effect on the fatigue life of a critically loaded part.
8. the type and amount of plating and/or painting which is used to protect a component in an adverse environment in general, leads to large, but necessary, additional costs.

It has been indicated that trade-offs usually occur in any selection process associated with the design process. The various effectiveness-to-cost ratios would be studied and vital decisions made by the designer, particularly when designing high performance machinery.

4.4 Achieving Economies in Manufacturing Operations

The choice of the most economical method of manufacture is often decided by the most readily available means. For example, if company A has a foundry, but company B does not; however, if company B has a forging facility while company A does not, then obviously it would be more economical for Company A to cast a crankshaft and company B to forge this component. Generally, these two methods of manufacturing are very competitive, especially if the volume or production is large.

After the designers have determined the functional requirements of a component, they are advised to consider how manufacturing cost is affected by such basic items as:

1 material cost
2. the production equipment suitable for the material selected
3. the volume of production, or more specifically, the yearly production to be scheduled
4 the tooling cost, which is basically a function of two parameters, first, the volume of production and second, the time which will be used to amortize the cost of the tooling.

If the volume of production warrants the use of expensive tooling, then the designer will be expected to design a product which is compatible with the available highly mechanized production machinery and facilities.

In performing a design review of a component, some general questions are:

1. Will the material specified be the most economical for the part?
2. Can the part be fabricated at an adequate production rate?
3. Will the physical shape lend itself to processing at the minimum cost and an adequate rate or volume of production?
4. Do dimensional tolerances permit selection of the most economical production methods?
5. Is the part design based on consideration of scheduled production volume?

The choice of the type of manufacturing process used is strongly dependent upon the projected volume of production and the desired market life. The volume of production is generally divided into three categories:

1. one-of-a-kind
2. low-volume manufacturing, that is roughly less than 250,000 units per year
3. high-volume manufacturing, that is, more than 250,000 units per year

The factor of market life is important with respect to the time you choose to amortize your tooling costs.

When a "one-of-a-kind" machine is produced, as little as possible should be spent for tooling. The use of standard components or purchased parts rather than expensive hand made parts can effect considerable savings. It is not unusual for 60% or more of the total costs to be in standard or purchased parts.

If a "low-volume" machine or device is being produced, any special parts made with low-production tooling are usually expensive. The parts should be designed so that they can be processed on standard tools such as shears, brakes, forming in a vee die, by single piercing, etc. Try to avoid the use of complex dies. Sand castings or investment castings should be considered in place of forgings or die castings. Screw-machine parts rather than cold-headed parts should be considered. Two simple parts in lieu of one complex part should be considered. Two simple parts in lieu of one complex part should be considered. The need for special gauges, assembly fixtures and calibration fixtures would be held to a minimum.

If "high-volume" production is indicated, then obviously, expensive tooling can be amortized effectively. For example, the effectiveness of forging parts can be realized because the volume of production can easily produce the necessary moneys to amortize the high initial cost of the forging dies and forging machine tools.

4.5 Selling-Price Analysis

4.5.1 Introduction

A simple system might be defined as one which contains a small number of components. On the other hand, a complex system such as a supersonic transport (SST contains a large number of components arranged in groups which are usually called sub-systems. A basic method of analysis of the selling-price for a simple system will be described. The same principles could be applied to estimate the selling-price of a complex system but the task is formidable and would require many man-hours to complete.

4.5.2 Types of Production Costs Which Enter Into The Computation Of The Selling Price

The types of production costs are the following:

1. direct material costs $/LB x No. of LBS.
2. direct labor costs $/HR. x No. of HRS.
3. indirect (overhead) costs of materials or the so-called burden (costs) on materials
4. indirect (overhead) costs of labor or the so-called burden (costs) on labor.

The above direct costs are generally easy to estimate and consequently a realistic number can be assigned to each. However, the above indirect costs are intangible and generally difficult to estimate. Usually, in a particular company, management and fiscal personnel will establish overhead factors to be used in estimating these indirect costs. Then these numbers, of course, are only valid for that particular company.

4.5.3 The Relationship of Unit Costs to Direct Costs

In order to compute direct production costs, it is necessary to obtain the unit costs of materials ($/lb.), and the unit costs of labor ($/hr.). then it is a simple matter to utilize total weight or total time to calculate total direct costs.

4.5.4 The Engineering And Drafting (E/D) Labor Costs Enter Into The Computation Of The Selling Price

The E/D costs can be estimated by employing unit labor costs ($/hr.) and the total number of E/D hours. Also, an overhead factor normally would be applied to take in account such items as management costs, facility costs and secretarial costs. Facility costs include the necessary physical plant and utilities.

4.5.5 Relationship of Operating Costs To The Selling Price

In general, the operating costs are not related to the selling price. The operating costs in most cases would be borne by the buyer of the system of device.

4.5.6 Relationship of Maintenance Costs to The Selling Price

In general, the maintenance costs are not related to the selling price. An exception, which probably will grow in practice, is in warranty situations such as employed by the automotive companies. In these instances some of the repair costs are borne by the original manufacturer and consequently these costs would be included in the selling price.

4.5.7 Miscellaneous and Administrative Overhead Costs (M/A) are Related to The Selling Price

The M/A type of costs, sometimes called the G/A (general and administration) costs, will be introduced as a factor applied to both production costs and E/D costs. This factor is applied to take care of a number of general manufacturing overhead items such as the following:

1. the cost of advertisement
2. the cost of market analyses
3. warranty costs

4. tax costs
5. insurance (on equipment) costs
6. cost of money (interest lost)
7. depreciation of plant equipment (tools)
8. administrative and legal costs
9. research costs

The depreciation of the physical plant (period 7 to 10 years) and cost or depreciation of utilities (period 15 to 20 years) is not included in the above, because these items will be taken into account in the overhead on production labor. This is an arbitrary decision. Also, the overhead on E/D labor will take care of the necessary physical plant and utilities for the Engineering Department.

4.5.8 Relationship of Profit to The Selling Price

As previously stated the selling price (SP) is

$$SP = IC + P \qquad (1)$$

Clearly an important principle is that all costs, all depreciation, everything, is included in the computation of the initial cost. Obviously, this is because corporation taxes are paid on profits.

4.5.9 Computation Of The Initial-Cost Of A System

It is convenient to define two types of initial costs. First, an IC which includes M/A costs, and second, an IC' which does not include M/A costs. This permits an estimate of IC' to be made and finally, a computation of IC, that is,

$$IC = (IC')(M/A\ factor). \qquad (3)$$

In expression (3), the (IC') is formulated as follows:

$$(IC') = \sum_i \text{(Mat '1 Costs)}_i \text{ (appropriate overhead factor)}$$

$$+ \sum_j \text{(purchased parts)}_j \text{ (appropriate overhead factor)}$$

$$+ \sum_k \text{(labor costs)}_k \text{ (appropriate overhead factor)}$$

$$+ \sum_1 \text{(E/D costs)}_1 \text{ (appropriate overhead factor).} \qquad (4)$$

In order to illustrate how an overhead factor is defined, the following computation of total material costs (TMC) is given.

TMC = Direct Material. Costs + Indirect Material. Costs

or,

TMC = DMC + IMC.

and, for example, if the indirect material costs are 10% of the direct material costs, then

$$TMC = DMC + (0.10)DMC$$

or,

$$TMC = (1.1)DMC, \quad (5)$$

and the overhead factor on materials is 1.1.

In order to compute the initial cost (IC') of a system, consider who each factor and element in equation (4) is estimated or computed:

1. Material costs = $/lb. x No. lbs. = A

2. Cost of Purchased Parts = PP

3. Labor Costs = $/hr. x No. hrs = B

4. Burden on Material = typically 10% of A

5. Burden on Purchased parts = Typically 10% of PP

Burden on material and purchased parts is introduced to take care of storage, handling and normal scrappage.

6. Burden on Labor = typically 130% of B. This burden is introduced to take care of:

   a. retirement of personnel

   b. cost of living increases

   c. depreciation of physical plant

   d. insurance for personnel

   e. insurance on physical plant and facilities

   f. downtime (idle time) of personnel and equipment

   g. operating costs of plant utilities

Consideration of depreciation of plant equipment was included in the M/A overhead, because a shorter depreciation period is used for plant equipment than is used for physical plant. That is, we have separated the way we handle depreciation on equipment from depreciation on plant. Downtime or idle time of personnel is dead time and involves such items as logistic problems (having the right men at the right place at the right time), labor disputes, coffee breaks, and even loafing.

7. E/D costs = $/hr. x No. of hrs. = C
8. Overhead on E/D costs = typically 25% of C

The M/A costs will be introduced as a percentage of IC', typically of IC'. Consequently,

IC = (IC') (M/A) (6)

IC = (IC') (1.15),

where the M/A overhead factor is 1.15.

Finally, substitution in equation (4) gives,

$$IC = \left[\begin{array}{l} \left\{ \sum_{Mat'1} i \left[\left(\frac{\$}{lb} \right) x \ No.\ lbs. \right] \right\} \{1.1\} \\ + \left\{ \sum_{P.P.} j \ [item] \right\} \bullet \{1.1\} \\ + \left\{ \sum_{labor} k \left[\left(\frac{\$}{hr.} \right) x \ No.\ hrs. \right] \right\} \{2.30\} \\ + \left\{ \sum_{E/D} 1 \left[\left(\frac{\$}{hr.} \right) x \ No\ hrs. \right] \right\} \{1.25\} \end{array} \right] [1.15] \qquad (7)$$

4.6 Profit

The profit would normally vary from 5% to 28% of the IC, depending upon various factors such as risk, competition, safety, image, etc.

4.6.1 Selling Price (SP)

The selling price for a case where the expected profit is 28% of I.C. is

SP = IC + P,

or

SP = IC + 028(IC),

or

SP = 1.28(IC).

4.7 Example: Estimation Of The Selling-Price Of An ACV - Warehouse Dolly

4.7.1 Brief Description of The Problem

The problem was to design a wheel less dolly for use by stock boys in warehouses. The vehicle had to operate on the air-cushion principle and use some or all of the intake air to accomplish floor sweeping. The important design criteria were low cost and lightweight. The cost was to be based upon a yearly production of 10,000 units. The prime source of energy was to come from a regular 220V, 60 cycle, 3 phase line. It was specified that the dolly carry a payload of 1000 pounds.

4.7.2 Production Costs Per Unit

A table of material costs, Table 4.1, was made for all manufactured components, that is, the material costs per component per machine. It was based upon the yearly production volume of 10,000 Units. Of course, there is considerable savings to be accomplished in volume buying of raw stock and manufactured components. A table of costs of purchased components, Table 4.2, provides a sub-total for those costs. Table 4.3, shows the direct labor times for all manufactured components.

TABLE 4.1 MATERIAL COSTS (100,000 UNITS/YEAR)

PER UNIT

Component	Quantity	Material	Specific Weight	Specific Cost	Total Weight	Total Cost
Angle Iron	62.8 ft.	Steel	2.44 lbs/ft	.20/lb	153.2 lbs	$30.64
Sheet Metal Covering	29.5 ft.	18 gauge. sheet steel	2.156 lb/ft^2	.20/lb	63.5 lbs	12.70
Ducting	1.05 ft^3	fiberglass	10.9 lb/ft^3	.75/lb	11.0 lbs	8.25
Motor	41.2 in^3	steel	0.283 lb/in^3	.20/lb	11.7 lbs	2.34
Brace						
Wood Deck	39 ft.	pine	--------------	.50/lb	20 lbs.	10.00
Cleaning System	13.5 ft^2	sheet steel	2.156 lb/ft^2	.20/lb.	28.6 lbs	5.72
Impeller	314 in^3	alum. alloy	0.100 lb/in^3	.75/lb.	31.4 lbs.	23.55
Weld Rod	-------------	---------------	---------------	1.00/lb	1 lb.	1.00
Motor Shaft	10 in^3	steel	0.283 lb/in^3	.30/lb	2.5 lbs.	0.75
TOTALS					323 lbs.	$94.95

TABLE 4.2: PURCHASED COMPONENTS (10,000 UNITS/YEAR)

PER UNIT

Component	Weight	Total Cost
Motor	80 lbs.	$58.00
Bearings	1 lb.	$5.02
Electrical Wiring*	----------------------------	$1.02
Switch	0.5 lbs.	$2.00
Misc. Bolts, Hinges, and Screen Dust Bag	5 lbs.	$0.50
*external cord not included		$71.52

TABLE 4.3: DIRECT LABOR TIME PER UNIT

Item	Hours Required
Cut frame members to size	3
Weld frame	2
Mold ducting*	1
Assemble ducting	3
Install motor and impeller shaft bearings	2
Weld sheet metal	3
Fabrication of wood deck and its attachment	1
Install Cleaning system	3
Electrical wiring and switch	1
Impeller and shaft	2
Handle	1
Bolts, hinges, and screen	1
*Mold costs were distributed over one year	
TOTAL	23

4.7.3 E/D Labor Time (Total, not per unit)

TABLE 4.4: ENGINEERING AND DESIGN LABOR

Engineering Labor	130 hours
Drafting Labor	70 hours
TOTAL	200 hours

4.7.4 Table of Totals

Now all the information on material costs, manufacturing costs, and cost of the purchased components, and E/D labor was brought together into a Table of Totals, Table 5.

Table 4.5: Table of Totals of ACV-Dolly System (10,000 units/yr.)

Element	Class of Effort`	Weight (lbs)	Drafting (hrs)	Engineering (hrs)	Material Costs	Purchased Items Cost	Prod. & Assemb., (hrs)	Testing Prototype	hours Normal
Motor	D	80	1	1.0	----	$58.00	1		
Bearings	D	1	1	2.0	---	5.02	1		
Wiring	D	----	1	0.5	----	1.00	0.5		
Switch	D	0.5	1	0.5	----	2.00	0.5		
Bolts, hinges, and screens	D	0.5	1	0.5	----	2.00	0.5		
Inlet ducting	B	5	10	10	4.25	----	1.5		
Dust Bag	C	----	1	0.5	----	0.50	3.0		
Outlet ducting	B	5	10	10	4.00	----	1.5		
Frame	C	150	10	10	30.64	----	5.0		
Impeller	A	30	10	50	23.55	----	1.0		
Shaft	C	2.5	10	2	0.75	----	1.0		
Cover (deck)	C	20	1	1	10.00	----	1.0		
Sides	C	60	10	1	12.70	----	3.0		
Weld Rod	D	0.5	1	30	1.00	----	3.0		
Handle	C	0.5	2	0.5	----	----	1.0		
Misc. Engr. time	----	----	----	10	----	----	----		
TOTALS		360	70	130	94.95	71.52	26	100	1

Class of Effort: A 50% to 100% R/D C. Std. with Co.

B. 00% to 50% R/D D. Off the shelf item

4.7.5 Cost Analysis to Obtain The Selling Price

1. Direct labor costs: 26 hrs. x $4.50/hr. = $117 per unit
2. Direct engineering costs: 130 hrs. x $10/hr. = $1300*
3. Direct drafting costs: 70 hrs. x $6/hr. = $420*
4. Prototype Testing: 100 hrs. x $8/hr. = $800*
5. E/D costs per unit

$$\frac{\$2520}{10{,}000} = \$0.25 / unit$$

6. Direct material costs = $94.95
7. Cost of purchased components = $71.52
8. The following overhead factors were provided by management

    1.1 on material and purchased parts

    2.3 on labor

    1.25 on E/D

    1.15 on M/A

9. Computation of the Initial Cost (IC)

$$IC = \{(117.)2.3 + (166.47)\ 1.1 + (0.25)\}\ \{1.15\} = (452.53)\ 1.15$$
$$IC = \$520 / \text{unit}$$

10. Computation of the Selling Price: Management specifics 20% profit

    SP = (IC) 1.2 = (520) 1.2

    SP = $624/unit

*amortized over 10,000 units.

4.7.6 Comments

A. The E/D costs will be written off in the first year.,

B. The prototype testing costs will be written off in the first year.

C. The E/D costs are almost negligible in this example because the annual rate of production is fairly large.