To budget a design project, you'll need an estimate of the time required to make the drawings. Here's a survey of 10 ways other people estimate, plus a new method by the author.

Estimating Drafting Time:

Art, Science, or

IS THERE A STANDARD FORMULA for estimating drafting time?

In November, 1970, the University of Wisconsin Drafting Institute assembled drafting leaders from around the country in a concerted effort to answer this question. While all agreed that estimating drafting time was of the greatest concern, nobody could cite a standard formula. Most companies, they concluded, based drafting-time estimates on historical data.

More recently, C. & R. Design conducted a search for all published data directly or remotely concerned with estimating. The results confirmed the Wisconsin findings. In hundreds of articles, from government documents to private company records, one thing was clear: there were many methods in use, but no standard procedure.

Eleven methods of estimating drafting time are listed in the Summary Table. Every known method is either listed or is a combination of those listed. No critical review will be undertaken individually; let it suffice that each method serves its own purpose. However, the essential elements useful to a comprehensive standard will be identified.

Summary of Estimating Methods

1. Estimate comprehensively from initial design through sustaining phase.
2. Operate within a given total hours ($) budget.
3. Cost plus fixed fee, charge time to completion.
4. Experience with similar jobs, scale up or down.
5. Fixed hourly figure based on type of drawing.
6. Incentive compensation system.
7. Hourly drawing index, average number of hours ($) per drawing.
8. Drawing size × pre-assigned complexity factor.
9. Hours per square foot × total number of square feet.
10. Size-exclusive factor.
11. Number of basic A units × hourly factor per A unit.

1 Comprehensive Estimate

A method for estimating comprehensively from initial design through the sustaining phase is illustrated in Table 1. The table summarizes the conclusions of Mr. Robert Hagaman, and was the subject of a paper he delivered at The Management Center of Cambridge and, later, at the University of Southern California. Hagaman's work urges estimators to consider all phases of a drawing's life cycle. Note that the total numbers are multiples of 4. Also note the trend of hours to double with a single increase in drawing size.

2 Budget Limits

At a Data Products Seminar in 1968, John Parker, Manager of Engineering Documentation at Aerojet General, stated, "It is best to get all the money you can. When money is gone, settle for the best design you were able to develop." Estimators may look askance at this practice, but they have all done exactly the same on occasion. This method is particularly applicable when new projects are planned which advance the state-of-the-art and have no history.

3 Cost Plus Fixed Fee

Cost Plus Fixed Fee is the practice of funding a project toward an objective. The objective may be a product of unusual reliability of performance or a pioneer effort. In this context, estimates are concerned with the objective design and its schedule. Drafting time is largely a bookkeeping entry charged to the customer.

4 Experience, Adjusted

Experience with similar jobs, scaled up or down, is often used for drafting estimates. Most companies have product lines or expertise in a product area. Therefore, when a second generation product is to be developed, the historical data compiled on the first unit is applied to the second unit.

5 Fixed Hourly Rate

Table 2 shows the hourly assignments used by an audio-visual engineering firm. It identifies the type

CESARE A. RAIMONDI
President
C & R Design
San Fernando, Calif.

Guesswork?

Table 1—Comprehensive Estimate of Drafting Time (hours)

Size	Design	Drafting	Checking	Total
		Initial Design & Drafting (to Release)		
A	2	4	2	8
B	4	8	4	16
C	6	12	6	24
D	8	16	8	32
E	10	20	10	40
J	20	40	20	80
+10% for supervision & administration				
		Manufacturing Phase		
A	1	2	1	4
B	2	4	2	8
C	3	6	3	12
D	4	8	4	16
E	5	10	5	20
J	10	20	10	40
+10% for supervision & administration				
		Sustaining Phase		
A	1	2	1	4
B	2	4	2	8
C	3	6	3	12
D	4	8	4	16
E	5	10	5	20
J	10	20	10	40
+10% for supervision & administration				
		Total (All Phases)		
A	4	8	4	16
B	8	16	8	32
C	12	24	12	48
D	16	32	16	64
E	20	40	20	80
J	40	80	40	160
+10% for supervision & administration				

Table 2—Drafting Time Estimate by Product Complexity

Drawing Type	Hours
Mechanical (detail, assemblies)	32
Schematic	32
Printed Circuit Layout (7 in. x 7 in.)	48
Printed Circuit Tape-Up	24
Printed Wiring Board (Fabrication detail)	8
Board Assembly	5
Revisions	16

Table 3—Drafting Task Standard

	Simple	Average	Complex
ASSEMBLY	20	40	60
CASTING			
Assembly	6	9	18
Fabrication	12	24	48
List of Materials	3	6	10
Machining	8	12	24
CHASSIS			
Equipment	8	12	16
Instrument	12	18	24
Intermediate	6	10	14
Power Supply	4	8	12
Printed Wiring Board	8	12	16
COVER			
Bottom	4	8	12
Enclosure	3	6	9
Rear	4	8	12

of drawing, and flatly enters the number of hours to be used in its estimates. Evidently this firm has found that on a 7 x 7-in. printed circuit board, the level of complexity is well contained by the hours assigned.

Note that most of the numbers are multiples of 4. One can visualize the Schematic as a D-size drawing, and the Tape-Up as a C-size. The PC Layout is shown as taking 48 hours, but it is probably the same size as the tape-up which takes 24 hours. Evidently, the company recognizes that the complexity of the design level effort requires double the hours a straight drafting task requires.

6 Incentive Compensation System

Table 3 shows part of a Drafting Task Standard chart. This is used in a plan that would motivate draftsmen to greater production by compensating them in addition to their normal hourly rate. Under this plan, various types of drawings are given an optimum time. The draftsman would earn a bonus by completing the assigned task in less than the estimated time.

Note that fixed hours are assigned by the type of drawing and complexity. Also note the multiples of 4 hr as a factor and the doubling of hours as complexity increases.

The author of this plan is betting that the draftsman can't make a drawing in the predicted time. Therefore, the target times in Table 3 are not easily achieved.

7 Hours/Drawing Index

An approach that has many variations is illustrated by an example:

15,000 drafting hours charged during year
500 drawings released

$$\frac{15{,}000}{500} = 30 \text{ hours per drawing}$$

The total number of drawings produced during a given time (perhaps the previous year) is divided into the total number of hours charged by drafting during the same period. This yields an average number of hours per drawing which is used as a "rule of thumb" in future estimates. The 30-hr average in the example is tantamount to saying "The average drawing produced in our drafting department is a D-size."

8 Size-Complexity Factor

An estimating chart used by a large space-rocket company is shown in Table 4. This is a combination system in which each drawing size is allocated three levels of complexity resulting in minimum, nominal, and maximum hourly estimates. In this method, the drawing size rather than the type of drawing is dominant. For the A-size drawing and complexity of 6.6, the estimate is 4 hr. Each increase in drawing size approximately doubles the number of hours required.

9 Hours/Sq Ft x Area Index

A manufacturer of electronic airborne equipment uses the hourly assignments shown in Table 5. In this method, the drawing size is discarded in favor of area in square feet to be determined by the drawing type. The drawing is first identified, then the estimator determines the approximate area to be used, and the multiplier is applied.

For example, a casting is assigned a multiplier of 3 hr per sq ft. If the casting is drawn on a C-size form (2.6 sq ft), the estimate would be $3 \times 2.6 = 7.8$ hr. Presumably, a larger casting would be drawn on a D-size form (5.2 sq ft), and would require $3 \times 5.2 = 15.6$ hr. The increase of drawing size from C to D doubles the hours required because the D-size drawing is twice the area of the C-size.

10 Size-Exclusive Factor

Table 6 shows the figures used by a California electronics company. This firm estimates drawings strictly on the basis of size, and for each size there is an hourly assignment. A schematic diagram or a gear train design layout drawn on a C-size form would be estimated at 16 hr each.

Table 4—Size-Complexity Factors

Dwg. Size	Square Feet	Complexity Factor	Total Hours
		3.8	2.3
A	.6	5.3	3.2
		6.6	4.0
		3.8	4.9
B	1.3	5.3	6.9
		6.6	8.6
		3.8	9.9
C	2.6	5.3	13.8
		6.6	17.2
		3.8	19.7
D	5.2	5.3	27.6
		6.6	34.2
		3.8	40.0
E	10.4	5.3	55.0
		6.6	69.0

11 The Basic A

Drawings are prepared on sheets of format paper, the smallest being A size, which measures 8-½ x 11 in. Each succeeding drawing size doubles in area so that a B size, 11 x 17 in., is equal to two A sizes. It is useful, then, to describe drawing area in units of A. Table 7 shows five standard drawing sizes with equivalent area and the corresponding A units.

Having established the Basic A units for each size of drawing, we need a multiplier for A to determine estimated hours per drawing.

A national telephone affiliate analyzing figures on 150,000 drawings determined its Basic A unit to be 2 hrs.

The electronics division of an aerospace company uses a figure of 3 hr per sq ft.

A radar and missile firm in New Jersey cites a 10-year history using 4 hr as the time standard for A.

In most of the estimating methods reviewed here, the hourly factor for the Basic A unit is 4 hr. In Table 7, then, the hours per drawing size are A = 4, B = 8, C = 16, D = 32, and E = 64.

The numbers in Table 7 could be used, and evidently are being used, with some degree of success. However, they must be regarded as raw numbers. As used here, the raw number is a starting-point figure, to be increased or decreased. Six factors must be defined and considered in adjusting the raw number to the actual hourly assignment used in the estimate.

Drawing Size: It is possible to draw a flat washer on an A-size drawing in one-half hour, or on an E-size drawing in the same time. But this is ab-

Table 5—Hours/Area Index

Hours per Sq Ft	Description
3.0	Housing Assembly with Gears
3.0	Match Set
2.5	Bearing Plate
3.5	Casting & Machining Drawings
3.0	Casting
2.5	Casting (machined)
3.0	Gear Assembly (anti-backlash)
2.0	Gear Detail
2.0	Gear shaft
2.5	Misc. Details (brackets, spacers, etc.)
3.0	Instruction Plates
1.0	Silk Screen Artwork
3.0	Printed Circuit Board Assembly
2.5	Printed Circuit Board
.5	Printed Circuit Board/Artwork
2.5	Printed Circuit Board/Schematic

Table 6—Size-Exclusive Factor

	New Design				
Description	A	B	C	D	E
Total	4.0	8.1	16.1	32.2	64.4

Table 7—Values for Basic A

Dwg. Size	Dimensions	Sq Ft	'A' Units	Hours per 'A' or Sq Ft
A	8½ × 11	.6	1	(4)
B	11 × 17	1.3	2	(8)
C	17 × 22	2.6	4	(16)
D	22 × 34	5.2	8	(32)
E	34 × 44	10.4	16	(64)

surd. The practice should be to select the smallest size sheet that will allow the fullest disclosure of the item and its features.

Checking: In the preceding methods, checking is sometimes prominent; in others, it is not mentioned at all. In some, it is part of the hourly factor. Checking time can be from zero to 100% of the drafting time. To determine the proper factor, the estimator must identify the type of checking required.

FORMAT: A format check is a minimum review of a drawing that considers the drawing presentation and basic elements of procedures.

FIT: A check for fit and function determines that all dimensions agree with all other parts of the end item under design. It includes format check.

TOLERANCE: In complicated mechanisms and equipment designs, all the parts in their minimum and maximum configuration must be studied under the proposed operating conditions. This type of check will also consider the value of the design itself and review the material selection, method of manufacture, and processes involved.

Data Acquisition: Before drawings can be started, the draftsman must acquire data pertinent to the design by some form of engineering input.

VERBAL: Verbal information presents problems in communication between the draftsman and his source, and problems in verification for the checker or supervisor. The uncertainty of verbal input increases the time to complete a drawing.

PARTIAL: Partial information is data acquired from existing information not fully documented or finally approved.

FIRM: Firm data is acquired from a fully approved and signed source. Example: A detail drawing of a chassis taken from an equipment layout drawing which has undergone a design review and has been signed by Engineering and Project Management.

Complexity: This can be described in terms of number of lines to be drawn, i.e. density, by the type of drafting, or the design requirements.

SCHEMATIC: These are relatively low density drawings, usually composed of single line connections of graphic symbols. Typical examples: electronic schematic, block diagram, logic diagram.

DETAIL: This category includes drawings which define the engineering requirements to fabricate, assemble, or install a part or unit. Examples: printed wiring board, chassis detail, specification control.

DESIGN: These drawings document design solutions for meeting the engineering requirements of an item. They depict design features to a degree where detail, assembly, and other drawings can be prepared. Examples: printed wiring layout, casting design layout, servo mechanism design, electronic equipment layout.

Level: The next item that must be considered is the drafting level: Mil-D-1000 categorizes drawings as Form 1, Form 2, and Form 3, relatable as follows:

MIL: These are contractor-prepared drawings that must meet stringent military requirements of format and quality.

STD: Many companies have a Drafting Room Manual which prescribes company standards for drawing style and content. This DRM may range from full Mil spec to fairly minimal guidelines.

FUNCTIONAL: These drawings are complete in

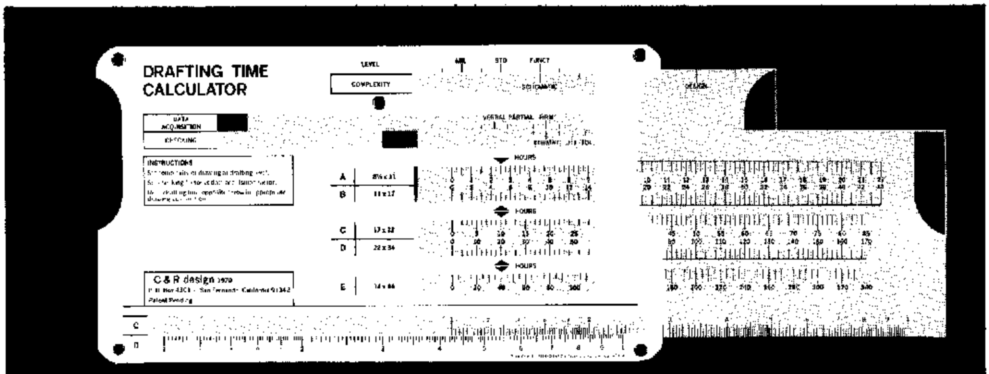

Fig. 1—Settings for a simplified drawing at Level rated Funct(ional) and Degree of Complexity rated Schematic. Engineering input, i.e. Data Acquisition, is scaled as Firm, with only Format Checking required. Time for an A-size drawing is read out as 2½ hr.

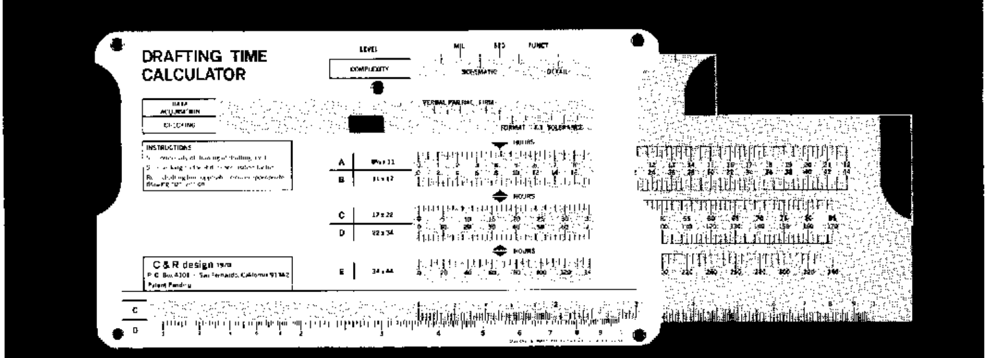

Fig. 2—Drafting Level, serving as the starting point or index, is shown at a softer (more confident) point than Funct(ional) for a Detail drawing. Alignment of Data Acquisition scales indicate all data to create drawing is known, i.e. Firm, and that Checking is minimized, i.e. Format type, or disregarded.

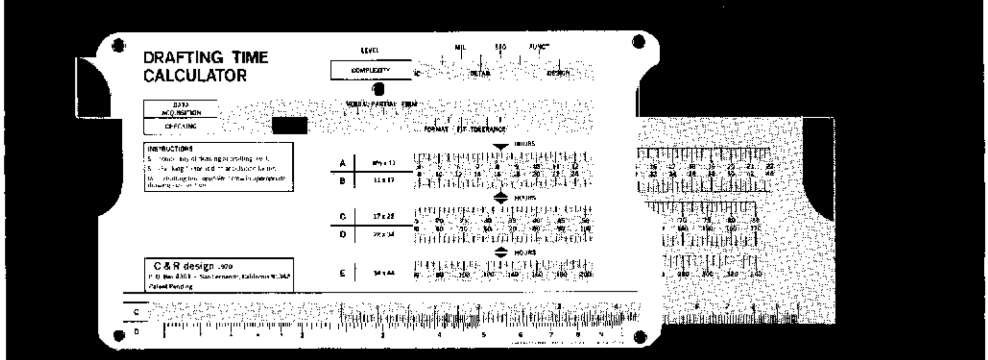

Fig. 3—Settings for a small part to be originated by a designer. No additional data is needed and there is no checking.

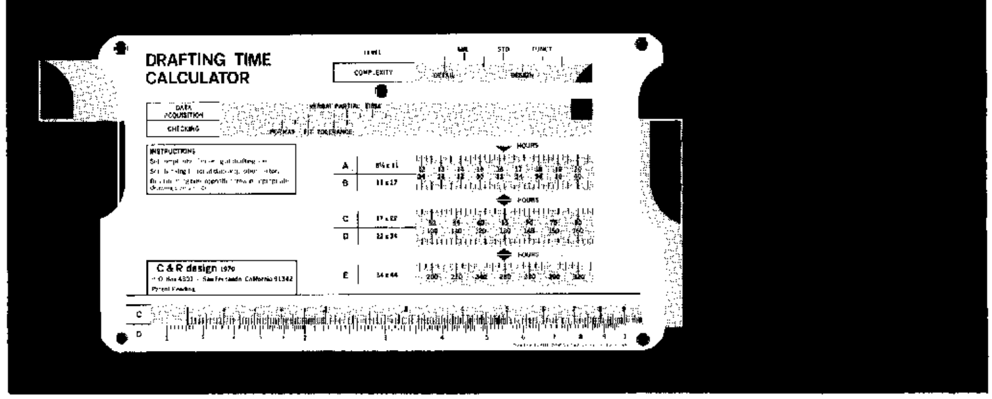

Fig. 4—Settings for Comprehensive Estimate method. Engineering input will dribble in and the drawings will require a full Tolerance check. Note that the value of 16 hr agrees with the total estimate for A-size drawings in Table 2.

content but accomplished in a minimal or simplified manner.

Efficiency: The last of the variables is an intangible. The average office worker in New York is claimed to be 52% efficient. The Wisconsin Drafting Managers round table concluded that draftsmen were 75% to 80% efficient. An English journal reports that a draftsman's time is spent as follows:

35% in drawing. This includes sketching, layouts and/or details.

24% away from his board.

27% in clerical duties, i.e., letters, form filling, estimates.

14% seeking references, in discussion and thought.

Allowances for these intangibles, the other five variables, and non-drawing time must be budgeted into the drafting department to provide for a drawing's full life cycle. It is not proposed that estimates be padded—only that they be assessed realistically. To illustrate how each of these factors can be applied and scaled to the exact nature of the drawing to be estimated we'll use a slide rule called the Drafting Time Calculator, Fig. 1, 2, 3, and 4.*

*Copies of the Drafting Time Calculator may be obtained from C. & R. Design, P. O. Box 4301, San Fernando, Calif. 91342. Price is $7.50 each.