A METHOD OF COST ANALYSIS FOR FARM STRUCTURES

by

ALLAN ARCHIBALD MCKILLOP

B. S., University of California, 1950

A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agricultural Engineering

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1951

TABLE OF CONTENTS

INTRODUCTION

One of the first questions a farmer asks when buying a tractor is how much does it cost. Furthermore, he expects an exact estimate, not one that may vary 50 percent from the final price that he will pay. If he is not satisfied with the price, he has the opportunity of looking at other models or foregoing its purchase as its usefulness may be far less than the cost of owning it.

An analogous situation arises with farm structures, only there are few qualified persons available who can determine, in advance, the cost. An estimate, at best, is only a rough approximation and often can vary as much as 100 percent. Therefore, it seems advantageous to find a simple, accurate system whereby the farmer can forecast the cost of a building.

Unfortunately little has been done with this phase of farm structures. There are in common use today several approximate methods--such as cost per unit animal or comparison with a building of similar construction; but since the price of labor and materials varies markedly throughout the country, costs applicable to one section may be far out of line in another section.

Today's farmer wants to know, as in the case of the tractor, whether a building is worth the cost of erection; and if by varying the type of construction, it might then be justified economically.

An investigation was undertaken to see if such an economic analysis for farm structures could be developed. Farm structures for the purpose of this investigation were construed to mean any building on the farm other than the home. Therefore, since farm buildings are, in general, rather basic in construction and since most professional estimators use the detailed estimating system, an attempt was made to modify it for application to farm buildings. Consequently, a major part of this investigation was devoted to finding those labor factors (the time in man-hours that is required to frame and erect a unit amount of material) suitable to farm construction.

In order to get a true comparison between farm labor and skilled labor, the study was divided so as to obtain labor factors for both types of builders. After suitable labor factors had been determined, a form was developed whereby an estimate could be calculated, knowing only the local prevailing prices of labor and of materials.

Finally several sample calculations were made to illustrate the following points:

1. Variation in different modes of construction.
2. Variation between skilled and unskilled labor.
3. Variations in building costs in different parts of the state.

REVIEW AND DISCUSSION OF IMPORTANT LITERATURE

Kinds of Estimates

Underwood (11, p. 1) defines an estimate as "essentially a computation of the probable cost of all materials necessary for constructing a building and the cost of all the labor required to arrange the material in place." He further states that it is not the actual cost of the building, but only an approximation. It is evident, then, the degree of accuracy desired will depend directly on the method employed to determine the estimate.

Carter and Foster (3) indicate that regardless of the type of estimate used, it may vary as much as 100 percent due to one or more of the following:

1. Location in area of high wages; materials must be shipped in.
2. Substitution of material qualities.
3. The utilization of native resources and home labor.

Types of Estimates. Barre and Sammet (2) list the following types of estimates:

1. Cost per square foot
2. Cost per cubic foot
3. Cost of comparable structure
4. Cost per animal unit
5. Detailed estimate

Underwood (11) adds to this the method of cost-plus-percent-for-labor. Dingman (6) mentions a wall to floor ratio method, but as this method is not in common use, it will not be discussed further. Most authors agree that numbers one, two, and five together with the cost plus labor are the most important and, therefore, each will be discussed as to its advantages, disadvantages and limitations.

Cost per Square Foot. The cost per square foot is the total cost of a building divided by the number of square feet of floor space (based on outside dimensions). A higher degree of accuracy can be obtained by using different cost factors for various floors of a structure. A quick estimate is obtained by multiplying the total square feet of floor by a uniform cost per square foot for the building. This method is well adapted to one story buildings (10); but should be used only as a rough check since labor, prices, plans, and modes of construction differ so widely throughout the country (8). In fact, this method is really accurate for just one building (the one for which it was calculated). It does serve its purpose, of course, in giving a quick method for determining the approximate cost of a building.

Cost per Cubic Foot. Cost per cubic foot applies the same principle as cost per square foot only volume is substituted for area. The cubic footage is based on the volume enclosed by the outside walls and roof of the structure. While this method is very similar to the cost per square foot, it is considered to be more accurate (8). To be of any value, however, accurate cost data must be kept and cost figures constantly revised; that is, experienced personnel only should use it. It has the decided disadvantage that the interpretation of the cubic footage differs so widely among professional estimators (2, 8, 11).

Each of these methods fails to differentiate between labor and materials. Consequently, there is no way to separate and adjust for labor efficiency and price differences. Other points that should be considered when using these two methods are as follows: that enough samples be taken to make the resulting figure representative; that the stage of completeness of the building be specified; that prices must be applicable to local conditions (2).

Cost-plus-percent-for-labor. This method entails calculating a bill of material, determining the material cost, and then adding a fixed percent for labor charge. Only an experienced man has the ability to judge which percentage is good for specific jobs. Where this method does make a distinction between labor and materials, the resulting estimate is not too accurate. Data must be continually recorded and constantly revised so as to apply the correct labor percentages (13). Once again, this method should serve only as a rough approximation.

The three methods just listed should be used by persons expert in the field of estimating so legitimate estimates can be obtained (1, 8).

The Detailed Estimate. Most estimators agree that this method is the only one that will give accurate results. Remember, however, that no estimate is absolutely reliable (2). The detailed estimate has the disadvantage of being time-consuming and of being laborious, but results obtained far exceed the effort spent in its preparation (10). The method necessitates knowing the time in man-hours to do certain basic jobs in the construction of a building (13). Then, simply by calculating a bill of materials, both the labor cost and the material cost can be calculated, and, an accurate estimate thereby determined. The main advantage of this method lies in the fact that variability among labor and prices can be adjusted to local conditions (8, 10, 11).

Barre and Sammet (2) list the following five headings as the proper sequence in the calculations of a detailed estimate:

1. Materials quantity survey
2. Estimate of labor hours required for each operation
3. Conversion to cost of materials and of labor
4. Additional expenses
5. Contingencies--cannot be added at the time of the estimate

Another advantage of this method is that once labor data have been compiled it is easier for a person who is not too well versed in estimating to calculate the cost of a building.

Essential Parts of an Estimate

Pulver (8) shows the following five divisions of an estimate, together with what he considers the approximate cost of each item expressed as a percent of the total cost:

1.	Materials - estimating quantity and cost	43.7 percent
2.	Labor - labor hours and cost	31.5 "
3.	Plant - equipment needed	-
4.	Overhead	15.3 "
5.	Profit	9.5 "

To this must be added the unforeseen items classified as contingencies (2, 11).

A materials survey has the advantage of making certain that everything is included in the estimate (2, 10); also it assures a means of obtaining an accurate bill of materials (2, 8). Most estimators use a form to aid them in picking off a bill of materials since it speeds up work and serves as a check. Underwood (11) notes that the sequence of items in an estimate usually follows the same order in which the operation will be performed in the field. There are, however, two disadvantages in using a form; one form cannot be complete enough to cover all jobs, and there may be a tendency to cover just the form and leave out important notes on the drawings (4). Generally a material survey is made from a set of blueprints (10).

The following are standard units employed in making a survey of materials which are used by estimators, including all of those listed as references: The units are based on how the material is priced and sold. Those listed are ones that are used in connection with farm structures. Also shown are the abbreviations that will be used throughout this manuscript.

Kind of work or material	Units	Abbreviations
Excavation or fill	Cubic yards	cyds.
Concrete		
Forms	100 Square feet	100 sq. ft.
Cement	Bag	bag
Sand	Cubic yards	cyds.
Aggregate	Cubic yards	cyds.
Reinforcing	Pounds	lbs.
Masonry		
Concrete blocks	1000 Units	M units
Bricks	1000 Units	M units
Tile	1000 Units	M units
Rock	Cubic yards	cyds.
Mortar	Cubic yards	cyds.
Lumber		
Dimensioned	Board feet	Fbm
	1000 Board feet	Mbm
Finished flooring	100 Square feet	100 sq. ft. (ft^2)
Siding	100 Square feet	100 sq. ft.
Wallboard	100 Square feet	100 sq. ft.
Insulation	100 Square feet	100 sq. ft.
Roofing	100 Square feet (Square)	100 sq. ft. (sq.)
Millwork	Per unit	per unit
Cornice	Lineal feet	lin. ft.
Eave trough	Lineal feet	lin. ft.
Drain, sewer	Lineal feet	lin. ft.
Painting	100 Square feet Gallon	100 sq. ft. gal.
Nails	Pounds	lbs.

The plant constitutes equipment that must be brought in and set up to aid in building operations; it usually applies to very large jobs (6). Therefore, it need not be considered in a detailed estimate for farm structures.

Overhead includes such items as Workmen's Compensation Insurance, Unemployment Insurance, Social Security, permits, supervision, and other expenses not directly associated with one particular job. For a person doing his own labor in building, permits will probably be the only item of importance; but when hired help is employed, whether it be a contractor or a local man, the other factors must be considered. Some farmers do not bother about Liability Insurance when hiring other local farmers, but to do so, means they are running a big risk. However, for small jobs the overhead is very low, but increases rapidly with size of job (8).

Profit is generally associated with a contractor. He is "interested in a day's work plus a small profit" (11). While the figure may vary depending on the size of the job--the smaller the job, the higher will be the contractor's percentage profit--it will usually run around 10 to 15 percent (8, 10).

Contingencies are those costs that inevitably appear on any construction job (1, 8, 10, 11). They might well be called risks since many chance elements are known to exist but for which no forecast can be accurately made. Probably the most important of these is the weather. Certainly it is quite variable; yet it has strong influence on time for construction and on efficiency of labor (11).

Townsend, Dalzell, and McKinney (10) point out that most towns of any appreciable size have laws or ordinances known as building codes. In any construction work, a builder should check all such codes before preceding with the work. If this is not done, it may cause undue expense at a later date. Probably the two items of building most affected by these codes are plumbing and wiring (1, 8). Generally, all work must pass a rigid inspection so that most contractors let sub-bids on plumbing and wiring (6). They find that it more than pays for itself. What makes things so difficult with respect to building codes is the lack of uniformity. Thus, the contractor must pass the inevitable higher cost on to the owner (10).

Labor and its Relationship to Estimating

The detailed estimate is dependable if all materials are taken into account and if the correct values are chosen for labor costs (11). This statement shows what extreme care must be taken in computing labor costs. Dingman (6) states that more attention should be directed to the method of obtaining and recording data as a function of production per man-hour rather than cost per unit. He further states:

> The possible production per man-hour is a reasonably constant quantity but money costs vary with every market change and, unless every condition is properly recorded, money costs reported for one operation may not be of any use in estimating the cost of a similar operation performed under different circumstances.

Pulver (8) indicates that the hour has replaced the day as a basic unit for labor costs since it is an exact period of time and since the day may vary from 6 to 12 hours, depending upon the individual.

With the data that are presently known, a refinement of labor factors, as unit of man-hour per production will henceforth be called, is not warranted closer than the nearest hour (6). Most published figures substantiate this idea.

The only way to obtain accurate labor factors is to keep cost-records on previous jobs—the more data, the better the factors (8, 10). Each time a new job is completed, labor factors should be refigured so as to be all inclusive (10). However, any labor factor obtained will represent only an "average performance" (2). Therefore, the degree of skill and the efficiency of individual men cannot be taken into account. However, as Townsend, Dalzell, and McKinney point out, if enough observations were averaged for a specific operation, the resulting labor factor would be safe to use for future references.

Table 1 from Underwood (11, p. 4) shows an approximate relationship between labor and material costs. It should be used only as a guide, but can serve as a check for large errors that might occur in an estimate.

Table 1. Proportion of labor cost to material cost.

Class of work	Labor cost divided by material cost
Forms for concrete	0.90
Concrete, job mixed	0.30
Concrete floor	0.36
Concrete blocks	
Foundation	0.48
Superstructure	0.74
Brick wall	0.55
Framing only	0.26
Framing and sheathing	0.29
Strip shingles	0.33
Windows	0.20
Painting, exterior	2.17

Much has been said about the efficiency of labor being at a low point, and it is true that men on an hourly wage tend to work less, meaning lower efficiency, than men on a contract job (11). Also, when labor is scarce and jobs are plentiful, efficiency tends to be low; the reverse situation will cause an upswing in labor production (8).

The price for labor varies not only throughout the country, but even between city and rural sections (6). Such publications as the Engineering News-Record keeps up-to-date figures on this change, both sectionally and nationally. However, it should be kept in mind that for any degree of accuracy in an estimate, it is best to consult local dealers and unions for prevailing prices (6, 8, 10, 11).

The following are standard units for labor factors together with abbreviations used in this manuscript. Once again, the units are used by most men in the field. It should be noted that several units are not the same as for survey of material, but conversion can be made without much trouble.

Kind of work or material	Units	Abbreviation
Excavation	Man-hours per cubic yard	mhrs/cyds.
	Machine-hours per cubic yard	machrs/cyds.
Forms	Man-hours per 100 square feet	mhrs/100 sq. ft.
Concrete	Man-hours per cubic yard	mhrs/cyds.
Masonry	Man-hours per 1000 units	mhrs/M units
Rock	Man-hours per cubic yard	mhrs/cyds.
Framing	Man-hours per 1000 board feet	mhrs/Mbm
Flooring	Man-hours per 100 square feet	mhrs/100 sq. ft.
Sheathing	Man-hours per 100 square feet	mhrs/100 sq. ft.
Roofing	Man-hours per 100 square feet	mhrs/100 sq. ft.
Siding	Man-hours per 100 square feet	mhrs/100 sq. ft.
Millwork	Man-hours per unit	mhrs/unit
Wallboard	Man-hours per 100 square feet	mhrs/100 sq. ft.
Insulation	Man-hours per 100 square feet	mhrs/100 sq. ft.
Painting	Man-hours per 100 square feet	mhrs/100 sq. ft.
Waterproofing	Man-hours per 100 square feet	mhrs/100 sq. ft.
Eave trough	Man-hours per lineal foot	mhrs/lin. ft.
Cornice	Man-hours per lineal foot	mhrs/lin. ft.
Drain	Man-hours per lineal foot	mhrs/lin. ft.
Wiring, rough	Man-hours per outlet	mhrs/fixture

Costs of Farm Structures

Carter and Foster (3) point out that farm buildings are much easier to estimate since overhead and profits can usually be neglected. Also, rural sections are not restricted so much as urban sections in the matter of building codes.

Strahan (9) argues that for the following reasons farmers cannot afford to do their own building:

1. Farmers can no longer afford to do the necessary building, even if they had the time.
2. They do not have equipment necessary to do an adequate job.
3. They are not mechanically qualified to get the full benefit from their building investment.

Regardless of Mr. Strahan's beliefs, a large part of farm construction is still done by farm labor. Barre and Sammet (2) clarify the point by saying " - of particular value is the estimate of man-hours of labor required, since this information is useful in judging whether it will be feasible to perform with farm labor the amount of work projected."

Wooley (12) gives the following figures as a labor-percent-of-material-cost: rough buildings, 20 percent; farmhouses, 40 percent; dairies, 33 percent.

Wooley (12) and Wooley and Beasley (13) devised a system of cubing which they used as a method of appraising farm structures. It consisted of taking plans for several different types of buildings and accurately figuring the material and labor requirements; then they determined material factors and labor factors in terms of the cubic footage of the building. Thus, for any building they wished to estimate, they merely took the cubic feet, multiplied it by the material and labor factor and adjusted to fit local prices. Consideration was made for differences in volume by subtracting a 2 percent decrease in factors for 10 percent change in volume.

Some studies have been made on the costs of farm structures (3, 4, 5). However, little value for general use is obtained since only specific cost data relating to a small section of the country were determined.

Barre and Sammet (2) do show the detailed estimating system, but fail to make any distinction between skilled labor and unskilled or farm labor. It is this point that should be stressed in any estimating scheme for farm structures.

A good point to remember in the economics of farm structures is that good construction does not always mean "pinching pennies" (14).

PROCEDURE FOR DETERMINATION OF LABOR FACTOR

Method of Collecting Data

The labor study was divided into two parts. The first dealt with collecting information from farmers who had done their own building; the second included gathering data from professional builders. Naturally, close correlation was necessary between these classes of workers, if comparable data were to be determined. Therefore, careful consideration was given to the following points.

Types of Structures to be Studied. As much as possible, information in both categories was restricted to farm structures. There was no difficulty experienced, in this respect, with farm labor, but it met with only moderate success in the case of skilled workers. However, all data collected were from structures of similar enough construction that comparable factors could be obtained. Silos were the one building that was not included in this study as they are almost always installed by the commercial firms from which they are purchased.

Types of Construction. To be truly representative, the major methods of construction—masonry, frame, and pole—were surveyed for both types of labor. Whenever possible, corresponding data were obtained for each job element timed.

Data to be Recorded. All data were recorded regardless of the source, and segregated at a later time. All known conditions under which each observation was performed were noted: the class of workers (skilled or unskilled); the material dimensions; the condition of the material (new or used); the types of tools; and other relevant information.

Method of Obtaining Data. From the start it was apparent that actual timing of operations was impractical. There were insufficient observers, and the time requirement for each operation was too long. Therefore, no attempt was made to break jobs down into basic elements such as time to walk a given distance with a load, time to hammer a nail, or time to saw a piece of wood. Rather, data were recorded as time to saw, frame, and erect a wall or partition or as time to mix, wheel, and place concrete. Another point in favor of getting readings in terms of complete jobs was that breaks for such things as talking and smoking were included. It was felt that such interruptions were an important part in the time study for any job, and, consequently should be part of the factor. Then if enough observations were taken, the average time for such interruptions would be included in the labor factor.

Number of Observations. Once again, no attempt was made to get an equal number of observations for all jobs. Some jobs proved more repetitive than others, and therefore, more information was available; also some parts of a building are unique in certain structures and appear so seldom as to be relatively unimportant.

Unskilled (or Farm) Labor. Two types of records were kept on farm structures. One consisted of gathering data on buildings that had been completed within the last year preceding the investigation; the other was directed toward information on structures that were built during the months that field observations were in progress. Unfortunately, construction time was so long that few personal timings were possible, all records being kept by the farmer.

As many buildings were surveyed as time would permit so as to reduce inconsistencies due to over or under evaluation of labor time. The following shows the types and number of structures visited.

Type of building	Number of observations
Hog house	3
Implement shed	10
Granary	7
Roundtop	4
Machine shed	5
Cattle shed	16
Dairy barn	13
General purpose barn	13
Sheep shed	3
Chicken house	11
Hay and feed barn	5
	90

Total time was recorded for completing specified jobs; this was later broken down into work elements per man-hour. Very seldom was a complete analysis made for each building since most farmers, when doing their own construction, must of necessity work at odd times and could not be expected to have reliable figures for such piece-meal work.

Skilled Labor. The professional builders contacted ranged from specialized or general contractors to local carpenters and masons. While the contractors did not specialize in farm structures, such data as they had referred to similar construction. Another point in favor of the contractors was that they were likely to have more complete cost-record data.

Each person who agreed to aid in this project was asked to fill out a form with data that were available to them. As much as possible, the form was correlated with information compiled under the farm-labor survey. The other source of skilled data was published figures. Forms were completed for each such reference, and later integrated with field observations.

Method of Analysis

All data were analyzed in two identical processes, corresponding to the divisions employed in the collection of them. Once the analysis had begun, no distinction was made as to the source of the reading. Every observation recorded was included in the analysis, unless it was definitely known to be erroneous. There was no reason to except or discard a reading because of its proximity to an "average figure". If there were large number of observations, one apparently out of line would not be weighed too heavily. On the other hand, if there were just a few readings, perhaps the one seemingly out of line was correct and the others inconsistent.

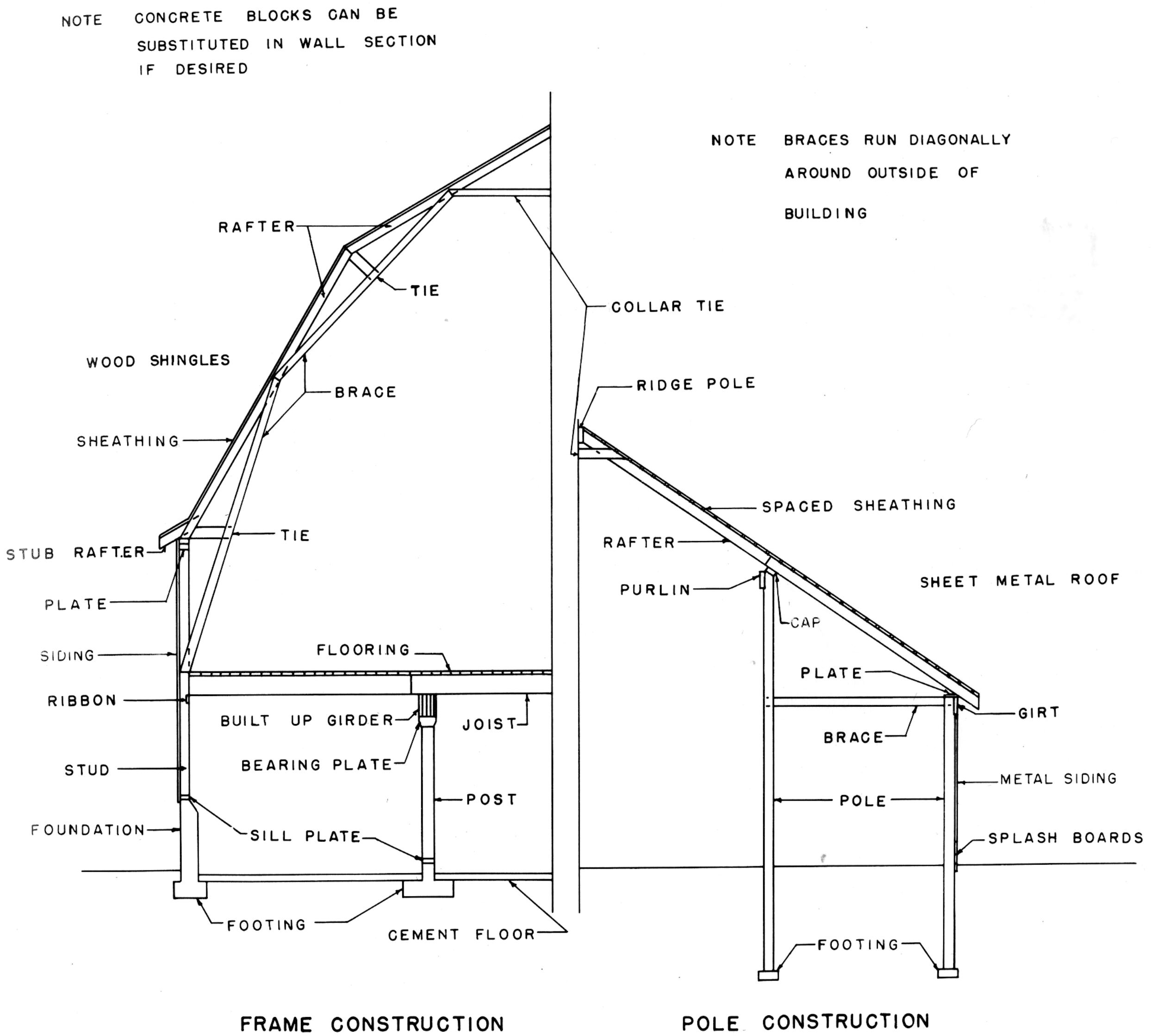


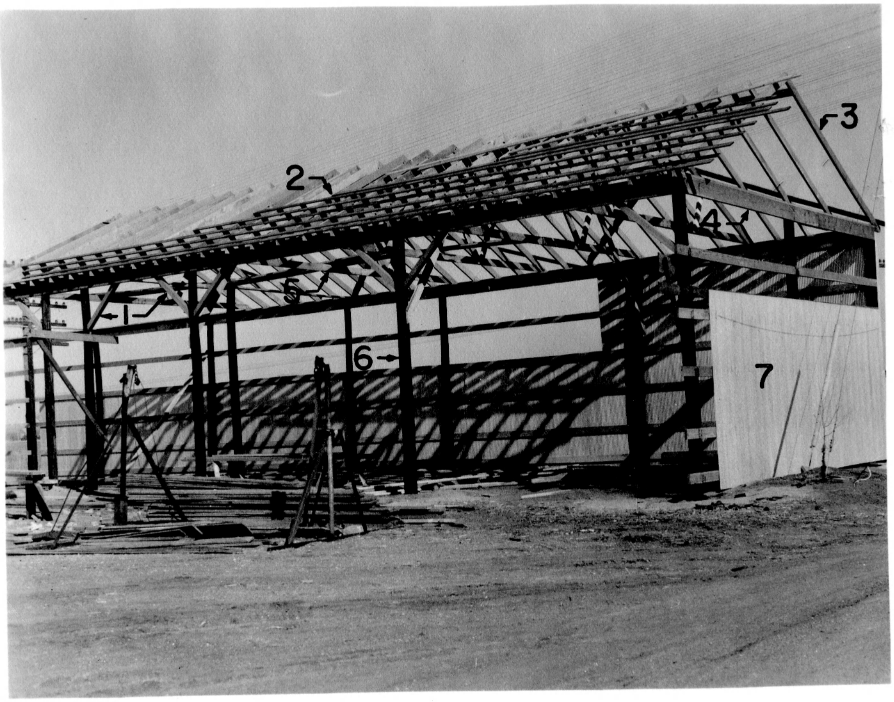
Fig. 1. TYPICAL CROSS SECTIONS SHOWING NOMENCLATURE USED IN THIS REPORT

EXPLANATION OF PLATE I

A pole type barn that is in construction showing the various parts.

1. Braces
2. Sheathing
3. Rafters
4. Girts
5. Joists
6. Poles
7. Sheet metal siding

PLATE I



A simple arithmetical average was employed in computing all labor factors; that is, the total of all the readings divided by the number of readings equalled the factor.

In the initial computations all data were analyzed at their basic level. Since all observations could not be broken down a like amount, component parts were first figured, then reassembled and checked with the other data. In the final analysis all possible regrouping was done so as to cut the number of labor factors to a minimum, yet still maintain accuracy. In some instances, where it was possible, conversion factors were applied to data to obtain uniform conditions for the purpose of the analysis. This was done with lumber. It is recognized that power sawing reduces time of framing to about 0.7. Therefore, all data were reduced to hand sawing by dividing by this number.

All factors were computed as single numbers, with the exception of excavation. The setting of limits seemed impractical since high and low readings may have differed by a multiple of 5 or 6. Eventually some one would have to select a particular figure, and it was thought that a person a little more familiar with the data could make a better selection.

The reason limits were set on excavation was due to the soils varying characteristics. Therefore, a person at the site of construction would be the only one competent to judge which soil factor was suitable.

RESULTS AND DISCUSSION OF LABOR FACTORS

Table 2 shows the final labor factors as determined by this investigation. Since the project was confined in area to the eastern half of Kansas, all factors are associated with construction and material prevalent in this section

Table 2. Labor factor.

Division	Class	Units	Skilled: Observations	Skilled: Factor	Unskilled: Observations	Unskilled: Factor	Remarks
Excavation	Hand	mhrs/cyd	6	1.6-1.0	48	3.9-1.6	1.6 and 3.9 refer to clay soil. 1.0 and 1.6 refer to sandy soil. Select factor according to makeup of your soil.
	Machine	machrs/cyd	6	.06-.04	-	-	See above.
	Backfill	mhrs/cyd	6	0.9	1	0.8	Scraper was used for part of the work.
	Grading	mhrs/cyd	4	1.0	2	1.2	Can be applied to any farm implement.
	Fill	mhrs/cyd	3	0.3	2	1.1	Machine time.
	Poles, hand	mhrs/pole	1	0.7	3	0.4	If soil is clay pan, double this figure.
	Poles, machine	mhrs/pole	-	-	1	0.08	Posthole digger.
Concrete	Forms						
	Foundation and footing	mhrs/sq. ft.	9	0.058	31	0.093	Area refers to contact area.
	Wall	mhrs/sq. ft.	8	0.091	-	-	Apply same factor for unskilled.
	Steps	mhrs/sq. ft.	3	0.14	-	-	Double for unskilled.
	Lintels and sills	mhrs/sq. ft.	3	0.12	-	-	See above.
	Mixing and placing	mhrs/cyd	8	2.7	49	2.3	Includes mixer and crew. Use for all concrete. Includes time for placing reinforcing.
	Ready-mix	mhrs/cyd	3	0.8	7	0.4	Placing only.
	Floor	mhrs/cyd	7	5.9	21	3.7	Refer to mixing and placing. Includes finishing.

Table 2. (cont.).

Division	Class	Units	Skilled Observations	Skilled Factor	Unskilled Observations	Unskilled Factor	Remarks
Masonry	Concrete blocks						
	8 x 8 x 16	mhrs/block	26	0.091	12	0.111	
	8 x 12 x 16	mhrs/block	8	0.132	-	-	Dobson block, pilasters and bracing included.
	Bricks	mhrs/brick	9	0.022	-	-	Common
	Tile	mhrs/tile	-	-	3	0.120	
	Rock	mhrs/cyd	15	3.6	-	-	Rubble for foundation.
Carpentry	Wall framing						
	New lumber	mhrs/Fbm	15	0.030	11	0.047	Includes studs, plates, headers, braces, girts. If power saw is used multiply by 0.7
	Used lumber	mhrs/Fbm	-	-	11	0.052	See above
	Plates	mhrs/Fbm	3	0.028	8	0.048	See above
	Studs	mhrs/Fbm	4	0.025	3	0.031	See above
	Poles, set and line	mhrs/pole	2	0.6	7	1.4	No framing included.
	Floor and ceiling joists	mhrs/Fbm	12	0.021	13	0.027	See wall framing.
	Girders and beams	mhrs/Fbm	5	0.022	5	0.033	See above
	Posts and columns	mhrs/Fbm	7	0.027	5	0.038	See above
	Rafters						
	New lumber	mhrs/Fbm	11	0.027	34	0.041	See above. For hip roofs
	Used lumber	mhrs/Fbm	-	-	14	0.047	increase by 15 percent
	Roundtop						
	Frame, erect	mhrs/Fbm	-	-	7	0.042	
	Prefabs	mhrs/rafter	-	-	3	3.2	
	Bracing	mhrs/Fbm	2	0.072	5	0.085	Applies to roof bracing.

Table 2. (cont.).

Division	Class	Units	Skilled		Unskilled		Remarks
			Observations	Factor	Observations	Factor	
Sheathing and flooring	Flooring, rough	mhrs/sq. ft.	13	0.020	5	0.033	For diagonal floors increase by 15 percent.
	Wall sheathing	mhrs/sq. ft.	10	0.020	7	0.064	See above. Use for gables.
	Roof sheathing	mhrs/sq. ft.	11	0.021	30	0.041	See above.
	Wall board	mhrs/sq. ft.	3	0.032	6	0.048	Includes time for sealing.
Siding	Asbestos shingles	mhrs/sq. ft.	7	0.041	5	0.068	
	Wood shingles	mhrs/sq. ft.	2	0.036	-	-	
	Sheet metal	mhrs/sq. ft.	5	0.023	7	0.031	
	Wood	mhrs/sq. ft.	15	0.030	12	0.035	Use for all types of common siding.
Roofing	Composition shingles	mhrs/sq. ft.	10	0.023	12	0.038	
	Wood shingles	mhrs/sq. ft.	12	0.037	18	0.060	
	Sheet metal	mhrs/sq. ft.	6	0.028	35	0.017	
	Roll	mhrs/sq. ft.	5	0.016	1	0.017	
	Cornice	mhrs/lin. ft.	5	0.027	4	0.083	
	Eave trough	mhrs/lin. ft.	4	0.077	4	0.060	Metal gutters and drain-spouts.
Doors and windows	Standard door						
	Hinged	mhrs/door	10	2.6	17	3.7	Includes doorframe and time for erecting. For estimate on framing of door use 0.030 mhrs/Fbm.
	Sliding	mhrs/door	3	6.7	-	-	See above. Includes placing track.
	Large (double)						
	Hinged	mhrs/door	4	3.5	3	5.3	See above.
	Sliding	mhrs/door	3	6.9	11	5.8	See above.

Table 2. (concl.).

Division	Class	Units	Skilled Observations	Skilled Factor	Unskilled Observations	Unskilled Factor	Remarks
Door and windows	Windows						
	Frame	mhrs/window	9	2.2	5	3.0	Includes windowframe.
	Masonry	mhrs/window	4	2.8	6	2.1	See above
Finishing	Waterproofing	mhrs/sq. ft.	3	0.007	2	0.014	For asphalt only, use painting factor for cement base.
	Painting						
	Wood	mhrs/sq. ft.	9	0.010	-	-	For each coat. Use for unskilled.
	Masonry	mhrs/sq. ft.	4	0.008	-	-	This can be used for waterproofing cement. Use for unskilled.
	Insulation	mhrs/sq. ft.	5	0.017	-	-	Regid or semirigid insulation.
	Drain (sewer)	mhrs/lin. ft.	1	1.0	-	-	Includes digging time.
	Wiring	mhrs/fixture	2	1.2	9	1.2	Rough work, does not include power lines.
	Strawloft	mhrs/sq. ft.	-	-	2	0.033	Includes wire and frame.

of the country.

One of the main points stressed in this investigation was the comparison between skilled and unskilled (or farm) labor. The results, in general, follow the expected pattern of skilled labor requiring less time per job than unskilled labor.

There were some notable exceptions in the results from what had been anticipated. Mixing and placing concrete, sheet metal roofing, and framing windows and doors all showed unskilled labor to be the faster. There are three possible explanations why this should happen:

1. The Speed of the Worker. A farmer when building is in a hurry to finish; he is not being paid, and has many other chores to occupy his time. A skilled laborer, however, works by the hour and is not worried about the completion time of a structure. This situation is especially applicable to concrete.

2. The Materials of Construction. Skilled carpenters work very little with certain materials used in farm structures, and therefore are unfamiliar with their construction. On the other hand, farmers, by helping one another, become quite adept at this type of building, and consequently know how to handle it. This reason covers the use of sheet metal.

3. The Type of Job. Except for windows and doors, the reversal in pattern was for those jobs that are more elementary in nature and require less skill in their performance. A farmer may be classified as unskilled; yet be very competent with a saw and hammer.

While some of the above reasoning applies to windows and doors, there seems to be little to substantiate the results obtained. Perhaps the only explanation lies in the final workmanship attained. However, labor for windows and doors is of minor importance in farm structures and will not affect the final estimate an appreciable amount.

All labor factors are recorded as man-hours per unit of production (for example, in framing, man-hours per foot board measure). The unit of production is used in all instances to facilitate ease of calculation with the estimating form.

Unless otherwise specified, an approximation for a missing factor can be obtained by using the corresponding one for the other class of worker. The only exception is used lumber for skilled labor. The same factor should be used for both conditions of lumber.

It should be recalled that all factors give the "average" time to complete a job. There are, of course, complications or simplifications on any job that may alter this time and consequently, throw the labor estimate slightly off. However, when all jobs are averaged over an entire structure, the observed and calculated values should be fairly close.

The question that would most likely arise concerning the data is the number of observations which compose some labor factors. It would be very desirable to have many more readings covering a larger section of the country. But so little is known about labor factors that any observation is better than none. Also, it should be noted that the more important jobs in construction were timed many times.

THE ESTIMATING PROCEDURE

An estimating form is probably the safest method of obtaining an accurate estimate. Its primary purpose is to assist and to simplify all necessary calculations. The form was evolved from the natural sequences followed in determining any estimate. To produce a form that would be completely self-explanatory meant unnecessary cumbersomeness. Therefore, it was found that a form correlated with an instruction sheet was the best solution. The form automatically takes care of the proper units. With the instruction sheet, the estimating form, and the labor factor table, the farmer should be able to compute the probable cost of a building.

An illustrative example will serve to show the proper use of the form. Assume the following conditions: a farmer living 5 miles from Manhattan wants to build a dairy barn of concrete blocks. The plan view and cross section are shown in Fig. 2. He intends to hire a mason and a carpenter; he will supply the other labor himself with the exception of pouring the concrete. This will be done with the aid of 5 neighbors. The wages are as follows; mason, $3/hr; carpenter, $1.85/hr.; farmers, $1/hr.

Instruction Sheet

Read the following carefully before proceeding to fill out the Estimating Form that accompanies these instructions.

1. Fill out the first part of the summary sheet. It contains dimensions and figures that will appear frequently in the calculations.

2. The form is divided into two sections. The first, columns B to C, accounts for the material needed in the building including the cost. The second, columns H to M, calculates the labor required in framing and erecting this material.

3. All calculations are based on nominal dimensions, and all prices are to be delivered prices.

4. All units for material and labor are specified at the head of each column unless otherwise indicated by item.

5. Remember that column F, unit price, and column L, labor wage, must be filled out with figures that <u>prevail</u> <u>in</u> <u>your</u> <u>locality</u> <u>at</u> <u>the</u> <u>present</u> <u>time</u>.

6. The remarks column is for the estimators convenience so as to note special details or instructions for specific items.

7. The labor factor is the time in man-hours that is required to frame and erect a unit amount of material. The correct figures can be obtained from the labor factor table. Whenever there is a combination of skilled and unskilled labor, a linear variation should be used to determine the proper factor. For example, if a carpenter and a farmer are framing, the labor factor is 1/2(.030 + .047) or .038.

8. The overage factor determines that amount of material that must be bought in excess of actual needs to allow for reduction in finishing and for waste. The following shows approximate overage factors:

Kind of material	Overage factor
Masonry	1.10
Framing	1.05
Sheathing and flooring	
Straight	1.15
Diagonal	1.20
Wallboard	1.05
Siding	1.30 - 1.80
Shingles	1.10
Sheet metal	1.10
Insulation	1.05

9. The following is an approximation for nail requirements:

Class of work	Pounds	Units
Framing	10-15	Mbm
Flooring	25-30	Mbm
Sheathing	25-30	Mbm
Wallboard	15-20	1000 sq. ft.
Siding	14	1000 sq. ft.
Shingles	40	1000 sq. ft.
Sheet metal	26	1000 sq. ft.

10. The following sample calculation will illustrate the proper use of the form. It will be accompanied by an explanation of how each item was obtained.

<u>The Material Calculation.</u>

A	B	C	D	E	F	G
Class	Pieces or lineal feet	Dimensions in x in x ft	Material Amount needed	Fbm Inclu. overage	Unit price	Material cost
Rafters	24 pc	2 x 6 x 12	288	302		
	24 pc	2 x 6 x 14	366	384	\$.135/Fbm	\$92.60

D = B x C $24 \times \frac{2 \times 6}{12} \times 12 = 288$ $24 \times \frac{2 \times 6}{12} \times 14 = 366$

E = D x overage factor 288 x 1.05 = 302 366 x 1.05 = 384 Fbm

G = E(Fbm) x F(\$/Fbm) = (302 + 384) x .135 = \$92.60

<u>The Labor Calculation.</u>

H	K	L	M
Lab fact mhrs/Fbm	Labor hours	Labor wage	Labor cost
.036	24.7	\$1	\$24.70

Laborers: 1 carpenter \$2/hr.

1 helper \$1/hr.

self no charge

H skilled = 0.027   Labor factor: 2 men x .041 = .082
unskilled = 0.041 $\frac{1}{3}$ man x .027 = .027

.109

$\frac{.109}{3} = .036$ mhrs/Fbm

K = E(Fbm) x H(mhrs/Fbm) = total man-hours 686 x .036 = 24.7 mhrs.

L Total labor cost per hour = $3

Number of men per hour = 3

Average unit labor charge = $\frac{\$3}{3}$ = $1/hr.

M K x L 24.7 x 1 = $24.70

Total cost of rafters N = G + M $92.60 + $24.70 = $117.30

11. Special instructions.

A. Concrete.

a. Forming is expressed in square feet of contact area. The factor of 2 takes this into account so if only one side is formed, do not multiply by 2.

b. D in cubic yards is obtained from $\frac{B \times C}{27}$

c. Base refers to any fill that may be used under the concrete floor.

d. If a mixer is rented be sure to add that charge to your estimate.

e. Add material cost of forms only if new.

f. For most concrete work the following quantities of materials can be used. The mix is 1; 2-1/4 : 3

1 cyd. = 6 sacks cement : .6 cyds sand : .8 cyds stone.

B. Masonry.

a. Determine net wall area as shown on form.

b. Multiply this area by one of the following factors to find the number of units required.

Concrete block	8 x 8 x 16	1.1
	8 x 12 x 16	0.74
Bricks		6.5

c. The following are approximate mortar requirements:

Stone	.24	cyds.	per cyd.
Concrete block	.0016	cyds.	per block
Brick	.00054	cyds.	per brick
Tile	.0016	cyds.	per tile

Cubic yard of mortar = 9 sacks of cement
90 lbs. of lime
1 cyd. of sand

C. Framing.

a. Prefabs are listed according to number of rafters for purpose of labor calculations. Labor hours are found by B x H.

D. Sheathing, flooring, siding, and roofing.

a. If 1" x 6" is used, the figures in columns B and D will be the same.

b. Labor hours are found by B x H. They are based on the total square feet that is to be covered. In the case of roofing use E x H.

c. Wall area to be covered can be computed using the method shown under Masonry.

E. Windows and doors.

a. Labor hours are found by B x H. It is figured on the number of windows and doors placed. Note that if door framing is to be done, the labor factor for framing should be used.

b. Hardware should be priced by the set. Time for installation is taken care of under (a).

F. Finishing.

a. Labor hours are found by E x H for insulation, stairs, and drains. For painting, and waterproofing use B x H.

b. Secure information on paint requirements from local dealer.

Summary Sheet

Date June 1, 1951

Owner E. R. Chubbuck

Location Manhattan, Kansas

Type of structure Dairy barn

Overall dimensions 32' x 24'

1. Outside perimeter 112' 2. Exterior openings (foundation) 14'

3. Net perimeter 98' 4. Lineal feet interior partition 35'

5. Interior openings 3' 6. Net feet of partition 32'

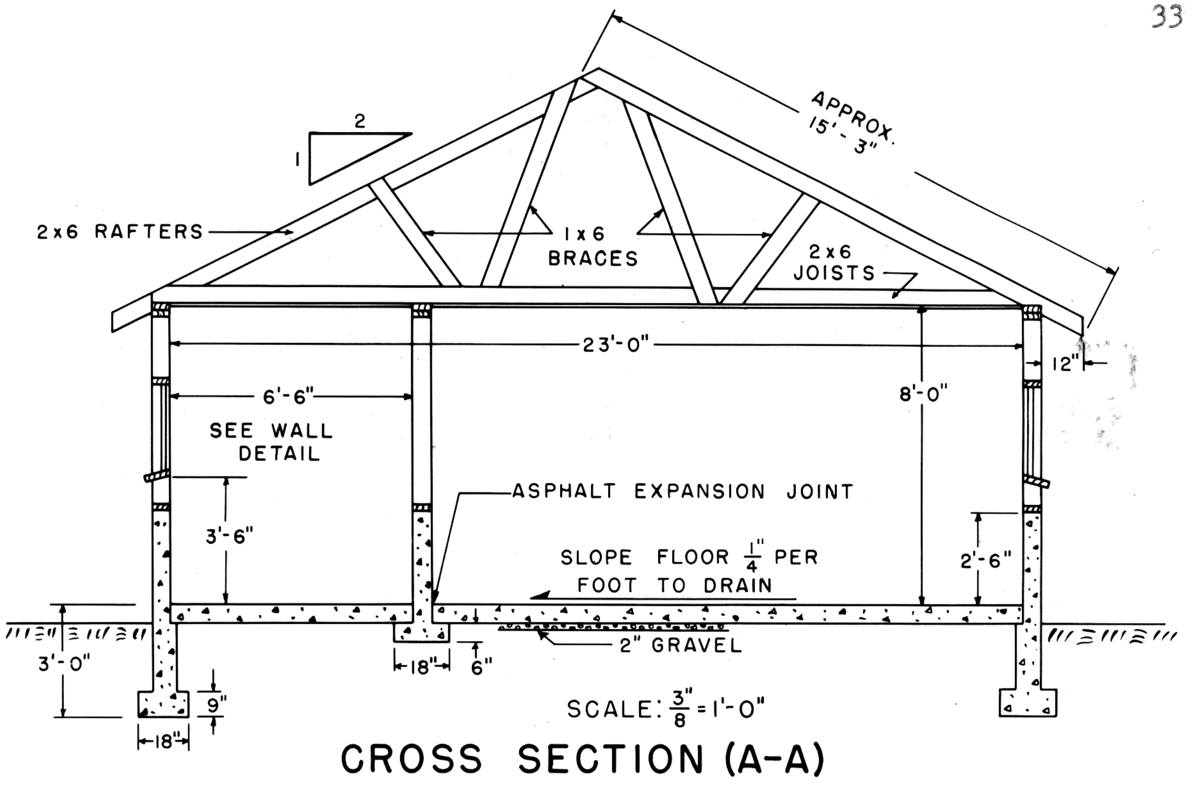
7. Height of wall (from foundation top to plate) 5.7'

8. Partition height if different from 7 5.2'

9. Door area, exterior 98 ft^2 10. Window area, exterior 60 sq. ft.

interior 21 ft^2 interior

Class	Material cost	Labor cost	Total cost
Excavation	-	$ 34.80	$ 34.80
Concrete	$ 528.80	201.84	730.64
Masonry	149.88	112.50	262.38
Framing	230.85	63.81	294.66
Sheathing and flooring	284.90	84.20	369.10
Siding	44.90	11.70	56.60
Roofing	185.20	70.35	255.55
Windows and doors	111.80	98.15	210.25
Finishing	38.70	6.00	44.70
Total	$1575.28	$ 684.39	$2259.67



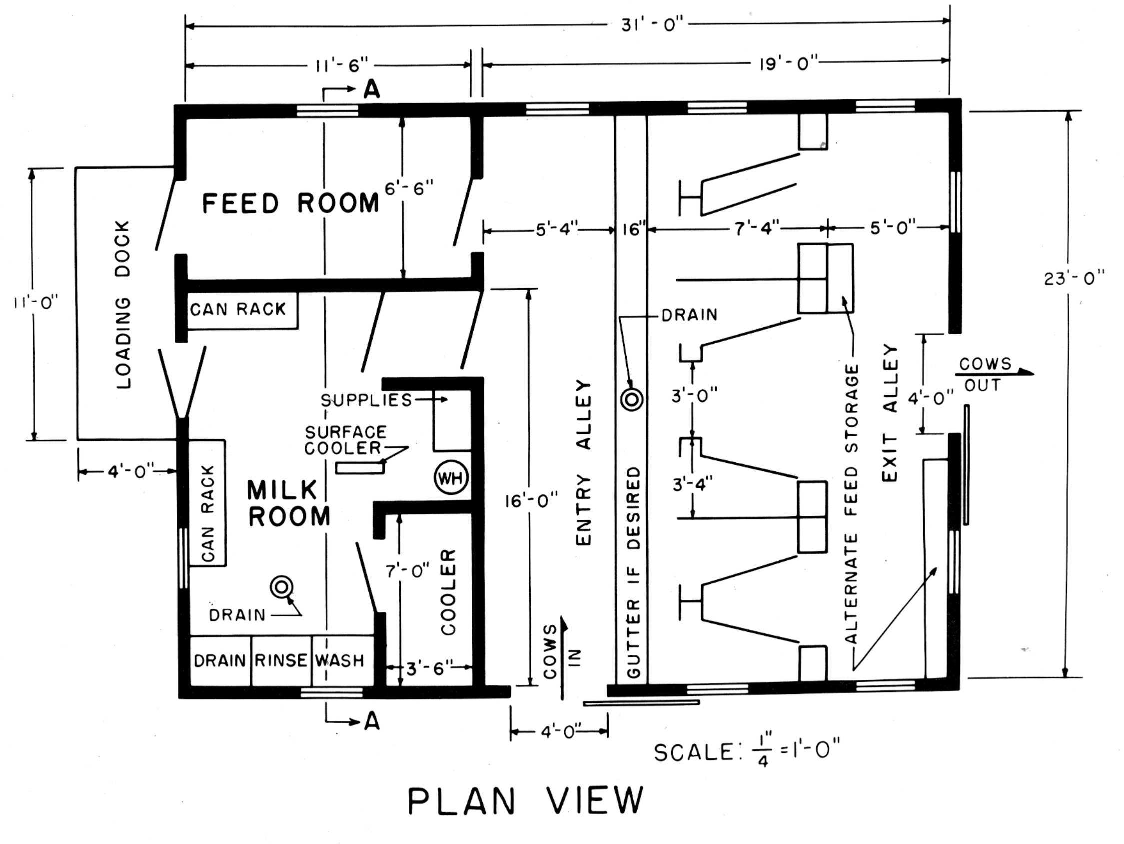


Fig. 2. Plan view and cross section of proposed dairy barn.

Estimating Form Sheet 1

Building Dairy barn

A	B	C	D	E	F	G		H	K	L	M	N

Excavation

Class	Lineal feet	Cross section ft x ft	Volume cyds	Material cyds	Unit price	Material cost	Remarks	Lab fact mhrs/cyd	Labor hours	Labor wage	Labor cost	Total cost
Found.	112	1.5 x 2.5	15.6									
	47	1.5 x .5	1.3									
	23	1.25 x .5	.5	17.4				2.0	34.8	$1	34.80	34.80
General		x										
		x										
Fill or grade	dp	x										
	dp	x										

Concrete

Class	Lineal feet	Cross section ft x ft	Volume cyds	Material sacks cyds	Unit price	Material cost	Remarks	Lab fact mhrs/cyd	Labor hours	Labor wage	Labor cost	Total cost
Forms	112	2 x 1.75 ht.	392 ft²					.076	29.8			
	130	2 x 3 ht.	780 ft²					.091	71.0			
	102	2 x .67 ht.	136 ft²					.12	16.3			
	30	2 x .67 ht.	40 ft²					.12	4.8			
		2 x ht.	ft²	Fbm						$.925	112.50	112.50
Footing	112	1.5 x .75	4.7									
	47	1.5 x .5	1.3									
Found.	112	1.75 x .65	4.8	Total concrete 34		352.80		2.3	48.3	$.87	42.00	394.80
Wall	130	3 x .5	7.2	or cement 204 bags	$1.10	224.00						
		x		sand 20.4 cyd	1.65	33.60						
Lintels	102	.67 x .67	1.7	stone 27.2 cyd	3.50	95.20						
		x										
Sills	30	1 x .5	0.6									
		x										
Floor	.5 dp	23 x 31	13.2									
	dp	x						3.7	48.9	$.87	42.50	42.50
Base	.167	23 x 31	4.4	5	2.00	10.00		1.1	4.84	$1.00	4.84	14.84
Reinfor.			1380 lbs.		.12	166.00						166.00

Masonry

	Outside wall		Inside partitions	
Gross wall area	112(1) x 5.3(7)	596 ft²	35 (4) x 5.3 (8)	187 ft²
Door area (actual area in wall)	9	98 ft²		21 ft²
Window area (actual area in wall)	10	50 ft²		ft²
Net wall area		448 ft²		166 ft²

Class	Units	Dimensions	Total number	Material units	Unit price	Material cost	Remarks	Lab fact mhrs/unit	Labor hours	Labor wage	Labor cost	Total cost
Concrete blocks	675	8"x8"x16"	675	743	$ .18	$134.00						
		x x										
		x x						.101	75	1.50	112.50	246.50
Brick		x x										
Tile		x x										
		x x										
Stone	lin	x	cyds	cyds								
	ft	x	cyds	cyds								
Mortar	743		1.2 cyds	cement								
			cyds	11 bags	$1.10	12.10						
			cyds	sand								
				1.2cyds	1.65	1.98						
				lime								
				110lbs.	.015	1.80						15.88

Estimating Form Sheet 2

Building Dairy barn

A	B	C	D	E	F	G		H	K	L	M	N

Framing

Class	Pieces or lin ft.	Dimensions in x in x ft	Material Fbm Amount needed	Material Fbm Inclu. overage	Unit price	Material cost	Remarks	Lab.fact. mhrs/Fbm	Labor hours	Labor wage	Labor cost	Total cost
Sills and plates	159 lin.	2 x 6	159	167	.135	$ 22.60		.039	6.5			
	44 ft	2 x 6	44	47	.135	6.35		.039	1.5			
		x								$.925	7.40	36.35
Studs	11 pc	2 x4 x 6'	44	47	.135	6.35		.039	1.5			
	22 pc	2 x4 x 8'	108	113	.135	15.25		.039	4.4			
	pc	x x										
	pc	x x								$.925	5.46	27.06
Headers	pc	x x										
	pc	x x										
	pc	x x										
	pc	x x										
Braces	pc	x x										
	pc	x x										
	pc	x x										
	pc	x x										
	pc	x x										
Poles	units	ft.	ft.									
	units	ft.	ft.									
	units	ft.	ft.									
Girts	lin ft	x										
		x										
		x										
Rafters	34 pc	2 x6 x16	544	570	.135	$ 77.00		.034	19.4			
	pc	x x										
	pc	x x										
Ridgepole	pc	x x								$.925	18.00	95.00
Ties and braces	34 pc	1 x6 x 6	102	107	.135	14.40		.079	8.4			
	34 pc	1 x6 x12	204	214	.135	28.80		.079	16.90			
	pc	x x								.925	23.40	66.60
Posts, beams, and girders	pc	x x										
	pc	x x										
	pc	x x										
Floor Ceiling Joists	17 pc	2 x6 x24	408	430	.135	58.00		.024	10.3	.925	9.55	67.55
	pc	x x										
	pc	x x										
		x x										
		x x										
		x x										
Nails	17 lbs.				0.12	2.10						2.10

Sheathing and Flooring

Class	Area to cover ft^2	Material cross section in x in	Material Fbm Amount needed	Material Fbm Inclu. overage	Unit price	Material cost	Remarks	Lab.fact. mhrs/ ft^2	Labor hours	Labor wage	Labor cost	Total cost
Wall		x	Fbm	Fbm								
Roof	1090	1 x 6	1090Fbm	1250Fbm	.135	169.00		.031	52.5	.925	48.50	217.50
Gables	120	1 x 6	120Fbm	138Fbm	.135	18.60		.042	7.8	.925	7.20	25.80
		x	Fbm	Fbm								
Floor		x	Fbm	Fbm								
Wall and ceiling board	714 ft^2		714 ft^2	770 ft^2	0.12	92.50		.040	30.8	.925	28.50	121.00
			ft^2	ft^2								
Nails	40 lbs				.12	4.80						4.80

Building Dairy barn

Siding (including gables)

Class	Area to cover ft²	Material cross section in x in	Material Amount needed	Material Incl. overage	Unit price	Material cost	Remarks	Lab fact. mhrs/ft²	Labor hours	Labor wage	Labor cost	Total cost
Wood	360	1 x 6	180 Fbm	188 Fbm	.135	25.40		.032	6.0	.925	5.60	31.00
		x	Fbm	Fbm								
Shingles	120			138 ft²	13.50	18.60		.055	6.6	.925	6.10	23.10
				ft²								
Metal				ft²								
				ft²								
Nails	5 lbs.				.18	.90						.90

Roofing

Class	Area to cover ft²	Material cross section	Material ft² Amount needed	Material ft² Inclu. overage	Unit price	Material cost	Remarks	Lab fact. mhrs/unit	Labor hours	Labor wage	Labor cost	Total cost
Shingles	1090			1250	.135	169.00		.055	68.8	.925	63.60	232.60
Metal												
Roll												
Cornice	132 lin ft	1 x 4	44 Fbm	46 Fbm	0.135	6.20		.055	7.3	.925	6.75	12.95
Eave trough	lin ft			lin ft								
Nails	56 lbs				0.18	10.00						10.00

Windows and Doors

Class	Quantity	Dimensions	Total Amount	Material	Unit price	Material cost	Remarks	Lab fact. mhrs/unit	Labor hours	Labor wage	Labor cost	Total cost
Window frames	60 lin	2 x6 x	60 Fbm	63 Fbm				Labor cost calculated under sashes				
	30 ft	x x	30 Fbm	32 Fbm								
		x x	Fbm	Fbm	.135	12.80						
Windows	10 ea.	27" x 27"			2.75	27.50						
	ea.	x										
Sheet mtal.	10 ea.	1ft² x				1.20		2.8	28	1.85	51.80	93.30
Door frame	70 lin. ft.	2 x 6	70 Fbm	74 Fbm				Labor cost calculated under doors				
		x	Fbm	Fbm								
		x	Fbm	Fbm								
		x	Fbm	Fbm	.135	10.00						
Doors	lin	x	100Fbm	105 Fbm								
	ft	x	70Fbm	74 Fbm								
	ea.	x	90Fbm	95 Fbm	.135	37.80		.03	8.8	1.85	8.15	8.15
	ea.	x										
	ea.	x										
	8 ea.	x						2.6	20.8	1.85	38.50	108.80
Nails	lbs.											
Hardware	2 set				5.00	10.00		Labor calculated under doors and windows				
	6 set				2.50	12.50						
	set											

Finishing

Class	Quantity	Dimensions	Total amount	Material	Unit price	Material cost	Remarks	Lab fact. mhrs/unit	Labor hours	Labor wage	Labor cost	Total cost
Painting	350 ft²			2 gals	5.95	11.90						
	ft²			gals				.01	5.5			11.90
Water-proofing	ft²											
Insulation	360 ft²			380 ft²	.07	26.60						
	ft²			ft²				.017	6.5	.925	6.00	32.60
Stairs	flight			Fbm								
Drain	lin ft											

RESULTS OF ILLUSTRATIVE CALCULATIONS

The estimating form and labor factor table are the important results determined in this investigation. However, several sample calculations were made to further illustrate the method developed, and to show comparisons due to different variations in construction.

Frame Construction

An estimate was again computed for the dairy barn (p. 30) only this time wood supplanted masonry as the type of construction used in the walls. The results showing a comparison between the two are given in Table 3.

Table 3. Comparison of costs of concrete block versus frame construction of a dairy barn.

Class of work	Material cost		Labor cost		Total cost	
	Block	Frame	Block	Frame	Block	Frame
Excavation	-	-	34.80	34.80	34.80	34.80
Concrete	528.80	528.80	201.84	201.84	730.64	730.64
Masonry	149.88	-	112.50	-	262.38	-
Framing	231.10	287.24	64.55	79.45	295.65	366.69
Sheathing and flooring	284.90	409.90	84.20	119.30	369.10	529.20
Siding	44.90	131.60	11.70	42.60	56.60	174.20
Roofing	185.20	185.20	70.35	70.35	255.55	255.55
Windows and doors	111.80	134.10	98.15	98.15	210.25	232.25
Finishing	38.70	50.40	6.00	6.00	44.70	56.40
Total	$1575.28	1727.24	684.39	651.49	2259.67	2378.73

In both cases, the farmer worked at all times with no pay. Had he hired helpers for the respective skilled men employed, it would have meant an additional cost of $309.39 for the masonry barn. As it was, the farmer contributed 251.5 hours of the total 652.8 hours needed for its completion.

Table 4 shows the breakdown for the man-hours required for building both types of dairy barn.

Table 4. Man-hours required to erect the dairy barn using either masonry or wood construction.

Class of work	Man-hours: Concrete block	Man-hours: Frame
Excavation	34.8	34.8
Concrete	223.9	223.9
Masonry	75.0	-
Framing	68.9	85.9
Sheathing and flooring	91.1	129.0
Siding	12.6	46.0
Roofing	76.1	76.1
Windows and doors	57.6	57.6
Finishing	12.0	30.5
Total	652.0	683.8

Finally calculations were made to determine what affect location has on building costs. The two locations chosen were Manhattan and Hutchinson since price data were available for both cities. A larger distance between towns would have better reflected the difference that does exist. The results are shown in Table 5.

Table 5. Cost comparison of a dairy barn reflecting price differences in Manhattan and Hutchinson.

Class of work	Material cost		Labor cost		Total cost	
	Manhattan	Hutchinson	Manhattan	Hutchinson	Manhattan	Hutchinson
Excavation	-	-	34.80	34.80	34.80	34.80
Concrete	528.80	492.90	201.84	211.34	730.64	704.24
Masonry	149.88	165.14	112.50	112.50	262.38	277.64
Framing	231.10	222.10	64.55	69.40	295.65	291.50
Sheathing and flooring	284.90	277.50	84.20	91.10	369.10	368.60
Siding	44.90	42.40	11.70	12.60	56.60	55.10
Roofing	185.20	116.00	70.35	76.10	255.55	192.10
Windows and doors	111.80	115.30	98.15	115.20	210.25	230.50
Finishing	38.70	47.00	6.00	6.50	44.70	53.50
Total	$1575.28	1478.44	684.39	729.54	2259.67	2207.98

Pole Type Structure

An estimate for the hay and feed barn owned by Mr. Marvin Hendricks of Alma, Kansas appears on the following pages. Mr. Hendricks was kind enough to keep records of material costs and of labor time. The labor for this structure was supplied by the owner and by a neighbor (they exchanged labor for similar buildings), neither of whom was paid.

If skilled labor had been employed, the labor cost would have come to $1000. This figure represents only the monetary savings gained by the use of farm labor. What this figure does not show is the lost time spent in doing other chores.

Summary Sheet

Date ____________________

Owner Marvin Hendricks

Location Alma, Kansas

Type of structure hay and feed barn

Overall dimensions 74 x 60

1. Outside perimeter ____ 2. Exterior openings (foundation) ____

3. Net perimeter ____ 4. Lineal feet of interior partition ____

5. Interior openings ____ 6. Net feet of partition ____

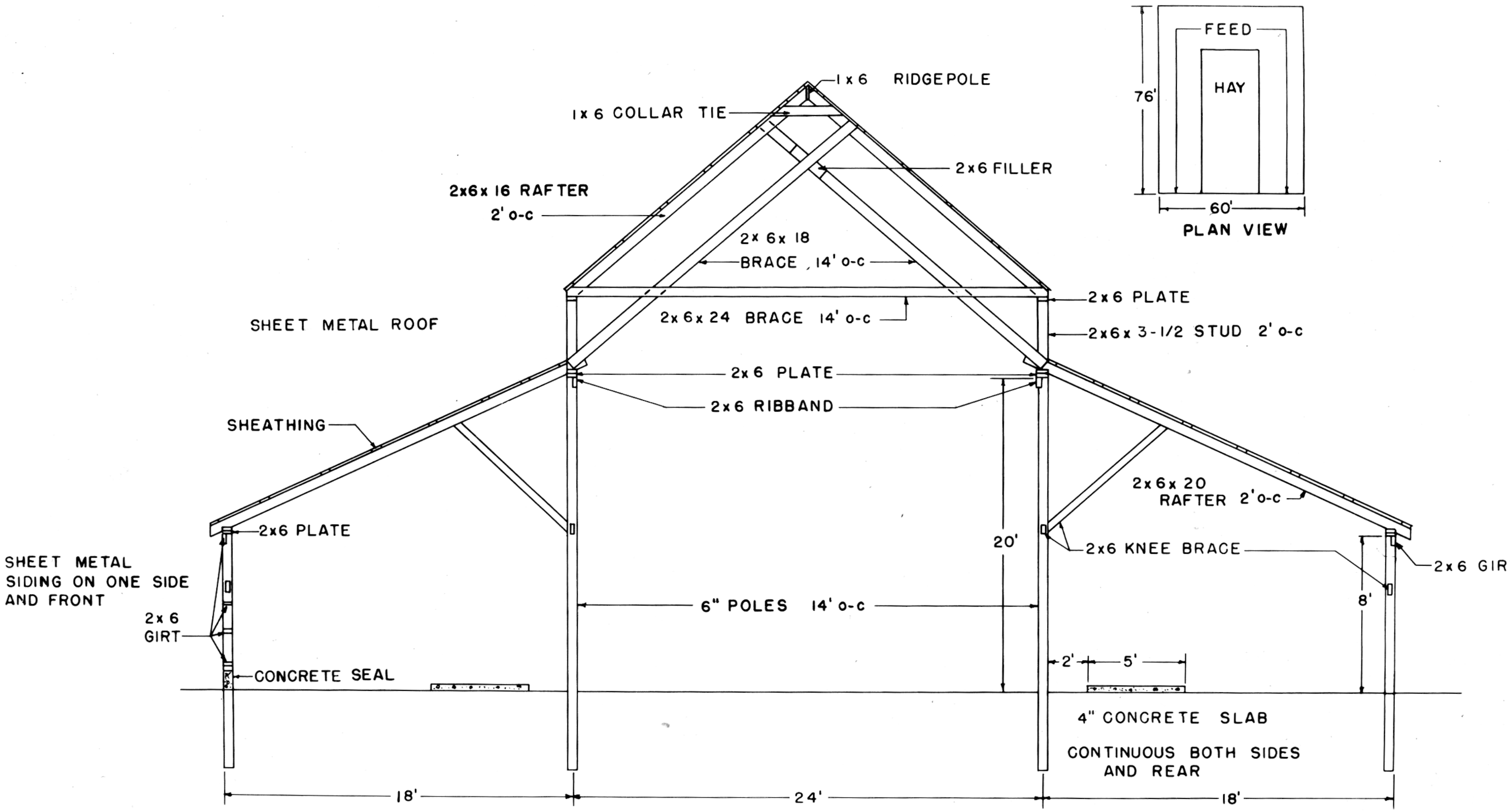
7. Height of wall (from foundation top to plate) ____

8. Partition height if different from 7 ____

9. Door area, exterior 370 sq. ft. 10. Window area, exterior 60 sq. ft.

interior ____ interior ____

Class	Material cost	Labor cost	Total cost
Excavation	-	-	-
Concrete	$82.80	-	$82.80
Masonry	-	-	-
Framing	$871.11		$871.11
Sheathing and flooring	$310.10		$310.10
Siding	$133.30		$133.30
Roofing	$718.70		$718.70
Windows and doors	$ 60.00		$ 60.00
Finishing			
Total	$2176.01		$2176.01



SCALE $\frac{1}{4}$" = 1'

Fig. 3. HAY AND FEED BARN

Building Hay and feed barn

A	B	C	D	E	F	G		H	K	L	M	N

Excavation

Class	Lineal feet	Cross section: ft x ft	Volume cyds	Material cyds	Unit price	Material cost	Remarks	Lab fact. mhrs/cyd	Labor hours	Labor wage	Labor cost	Total cost
Found.		x										
		x										
		x										
General	33 poles	x										
		x						0.8	26.4			
Fill or grade	dp	x										
	dp	x										

Concrete

Class	Lineal feet	Cross section: ft x ft	Volume cyds	Material sacks cyds	Unit price	Material cost	Remarks	Lab fact. mnrs/cyd	Labor hours	Labor wage	Labor cost	Total cost
Forms	99	2 x 1 ht.	198 ft²					.093	1.8			
		2 x ht.	ft²									
		2 x ht.	ft²									
		2 x ht.	ft²									
		2 x ht.	ft²	- Fbm	-	-				-	-	
Footing		x										
		x										
Found.	99	6 x 1	2.0	Total concrete								
		x		11.5 or				2.3	4.6			82.80
Wall		x		cement 70 bags	1.00	70.00						
		x		sand 6.9cyd	1.85	12.80						
Lintels		x		stone 9.2cyd	-	-						
		x										
Sills		x										
		x										
Floor	4" dp	5 x 154	9.5									
	dp	x						3.7	35.2			
Base		x										
Reinfor.			lbs.									

Masonry

	Outside wall		Inside partitions
Gross wall area	(1) x (7)	ft²	(4) x (8) ft²
Door area (actual area in wall)	9	ft²	ft²
Window area (actual area in wall)	10	ft²	ft²
Net wall area		ft²	ft²

Class	Units	Dimensions	Total number	Material units	Unit price	Material cost	Remarks	Lab fact. mhrs/unit	Labor hours	Labor wage	Labor cost	Total cost
Concrete blocks		x x										
		x x										
		x x										
Brick		x x										
Tile		x x										
		x x										
Stone	lin	x	cyds	cyds								
	ft	x	cyds	cyds								
Mortar			cyds	cement bags								
			cyds	sand cyds								
			cyds	stone cyds								

Estimating Form Sheet 2

Building Hay and feed barn

A B C D E F G H K L M N

Framing

Class	Pieces or lin ft.	Dimensions in x in x ft	Material, Fbm Amount needed	Material, Fbm Inclu. overage	Unit price	Material cost	Remarks	Lab fact. mhrs/Fbm	Labor hours	Labor wage	Labor cost	Total cost
Sills and plates	762lin.	2 x 6	762	800								
	ft	x										
		x			.13	$104.00		.047	37.6			104.00
Studs	58 pc	2 x 6 x3 1/2	204	214								
	pc	x x										
	pc	x x										
	pc	x x			.13	27.80		.047	10.1			27.80
Headers	26 pc	2 x 6 x 3	78	82	.13	10.70		.047	3.9			
	13 pc	2 x 6 x 2	26	27	.13	3.52		.047	1.3			
	pc	x x										
	pc	x x										14.22
Braces	37 pc	2 x 6 x 6	222	233	.13	30.25		.047	11.0			
	11 pc	2 x 6 x 8	110	116	.13	15.10		.047	5.4			
	20 pc	2 x 6 x12	280	294	.13	38.20		.047	13.8			83.55
Brace	4 pc	2 x 6 x 4	16	17	.13	2.20		.047	.8			
Ribband	pc	2 x 6 x 136	136	143	.13	18.60		.047	6.7			20.80
Poles	20 units	12 ft	ft		6.00	120.00		1.4	28.0			
	13 units	20 ft	ft		3.00	39.00		1.4	18.2			
	units	ft	ft									159.00
Girts	288lin	2 x 6	228	240	.13	31.70		.047	10.7			
	325ft	2 x 6	325	-	-	-		.052	16.9			
	172	2 x 6	172	182	.13	24.30		.047	8.1			56.00
Rafters	91pc	2 x 6 x 20	1820	1910	.13	248.00		.041	78.2			
	58pc	2 x 6 x 16	928	975	.13	127.00		.041	40.0			
	pc	x x										
Ridgepole	1 pc	1 x 6 x 58	26	28	.13	2.64		.041	1.2			377.64
Ties and braces	6 pc	2 x 6 x 18	72	76	.13	9.90		.047	3.6			
	3 pc	2 x 6 x 24	72	76	.13	9.90		.047	3.6			
	pc	x x										19.80
Posts, beams and girders	pc	x x										
	pc	x x										
	pc	x x										
Floor Ceiling Joists	pc	x x										
	pc	x x										
	pc	x x										
		x x										
Brace	4	1 x 6 x 20	40					.052	2.1			
Brace	3	2 x 6 x 3	9	10	.13	1.30		.047	.5			1.30
Nails	54 lbs				.13	7.00						7.00

Sheathing and Flooring

Class	Area to cover ft²	Material cross section in x in	Material, Fbm Amount needed	Material, Fbm Inclu. overage	Unit price	Material cost	Remarks	Lab fact. mhrs/ft²	Labor hours	Labor wage	Labor cost	Total cost
Wall		x										
Roof	2016	1 x 6	2016	2320	.13	301.00		.041	95.20			301.00
Gables		x										
		x										
Floor		x										
Wall and ceiling board			ft²	ft²								
			ft²	ft²								
Nails	70 lbs				.13	9.10						$ 9.10

Building Hay and feed barn

A	B	C	D	E	F	G		H	K	L	M	N

Siding (including gables)

Class	Area to cover ft²	Material cross section in. x in.	Material Amount needed	Material Inclu. overage	Unit price	Material cost	Remarks	Lab fact. mhrs/ft²	Labor hours	Labor wage	Labor cost	Total cost
Wood		x	Fbm	Fbm								
		x	Fbm	Fbm								
Shingles				bun.								
				bun.								
Metal	1154			1270ft²								
				ft²	.105	133.30		.031	39.4			133.30
Nails	lbs											

Roofing

Class	Area to cover ft²	Material cross section	Material, sqft: Amount needed	Material, sqft: Inclu. overage	Unit price	Material cost	Remarks	Lab fact. mhrs/ft²	Labor hours	Labor wage	Labor cost	Total cost
Shingles												
Metal	5952			6550								
					.105	688.00		.017	111.1			688.00
Roll												
Cornice	lin	x	Fbm	Fbm								
Eave trough	lin ft			lin ft								
Nails	185 lbs				.165	30.70						30.70

Windows and Doors

Class	Quantity	Dimensions	Total amount	Material	Unit price	Material cost	Remarks	Lab Fact. mhrs/ft²	Labor hours	Labor wage	Labor cost	Total cost
Window Frames	pc	x x	Fbm	Fbm				Labor cost calculated under sashes				
	pc	x x	Fbm	Fbm								
	pc	x x	Fbm	Fbm								
Windows	ea.	x			2.90	37.70						
	ea.	x										
	ea.	x						3	39			37.70
Door Frame	lin ft		Fbm	Fbm				Labor cost calculated under doors				
			Fbm	Fbm								
			Fbm	Fbm								
		x	Fbm	Fbm								
Doors	60 lin	2 x 4	40 Fbm	42 Fbm								
	40 ft	2 x 6	40 Fbm	42 Fbm								
	56	2 x 6	56 Fbm	60 Fbm	.13	1.90		.041	5.9			
	1 ea.	20 x 12						5.8	5.8			
	1 ea.	12 x 7						5.8	5.8			
	1 ea.	3 x 7						3.7	3.7			22.30
Nails	lbs											
Hardware	set	track 40 lin ft.			.51/ft	20.40						
	set							Labor calculated under doors and windows				
	set											

Finishing

Class	Quantity	Dimensions	Total amount	Material	Unit price	Material cost	Remarks	Lab fact. mhrs/ft²	labor hours	Labor wage	Labor cost	Total cost
Painting	ft²			gals								
	ft²			gals								
Water-proofing	ft²											
Insulation	ft²			ft²								
	ft²			ft²								
Stairs	flight			Fbm								
Drain	lin											

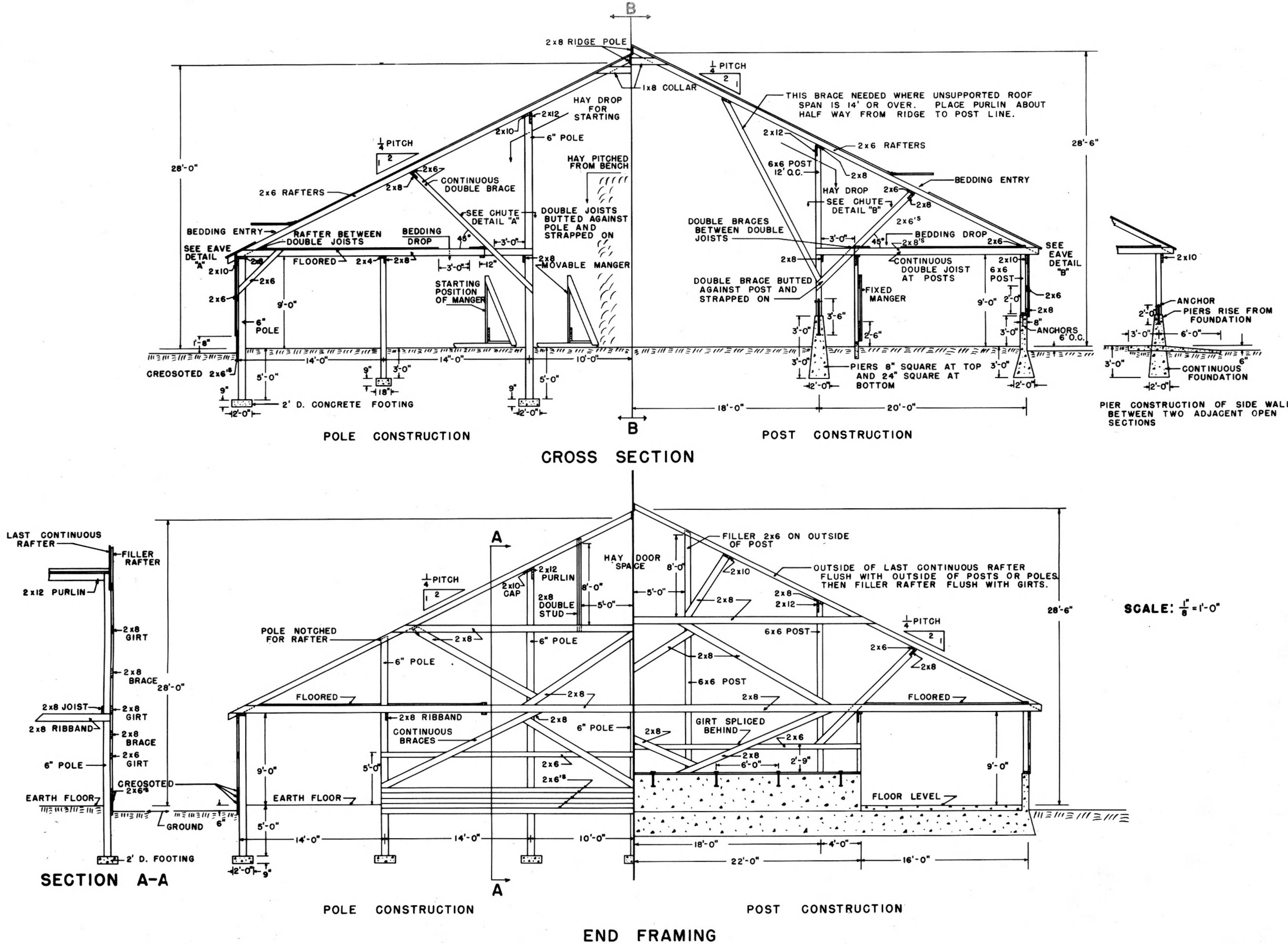


Fig. 4. Cross section and end section of hay and feed barn showing both pole and frame construction.

It will be noticed that under girts in the framing section there is no charge for material. This illustrates the method that should be applied when used material is employed.

Pole Versus Frame Construction

Much has been written concerning the pros and cons of pole construction over frame construction. Perhaps, however, its chief advantage lies in its low construction cost. The following example (Fig. 4) shows a comparison between these two types of construction.

The particular building chosen was designed either as a pole or frame structure, and therefore, should give an excellent comparison. All prices were those prevailing in Hutchinson on June 15, 1951. For the purpose of the estimate the following labor compliment was used: a carpenter, 2 farmers (hired), and the owner. Materials used (other than shown on cross section) were as follows: sheet metal siding and roofing, ready mix concrete, and spaced sheathing. The results may be found in Table 6.

The labor hour requirement for the pole barn was 996.5 hours, and for the frame barn was 1446.6 hours. While this shows a decided advantage for the pole type structure both in cost and man-hours of labor, it should not be construed from this one example that such will always be the case.

This same barn with solid sheathing and composition shingles would cost $878.89 more and would add 384 hours to the labor time.

Table 6. Cost comparison of pole type versus frame type construction of a hay and feed barn.

Class of work	Material cost		Labor cost		Total cost	
	Pole	Frame	Pole	Frame	Pole	Frame
Excavation	--	--	13.30	20.00	13.30	20.00
Concrete	45.00	1432.00	7.40	519.50	52.40	1951.50
Masonry	--	--	--	--	--	--
Framing	1549.00	1442.40	470.00	436.00	2019.00	1878.40
Sheathing and flooring	838.50	838.50	202.00	202.00	1040.50	1040.50
Siding	524.85	425.00	119.00	99.00	643.85	524.00
Roofing	1028.00	1028.00	160.60	160.60	1188.60	1188.60
Windows and doors	15.45	15.45	16.00	16.00	31.45	31.45
Finishing	--	--	--	--	--	--
Total	$4000.80	5181.35	988.30	1453.10	4989.10	6634.45

SUMMARY

The importance of getting an accurate bill of materials has already been stressed; however, it will be well to summarize a few points necessary in obtaining one. The first step consists of taking a bill of materials directly from a set of blueprints. These plans consist of a plan, a cross section, and other sufficient details to make clear the construction of a proposed building. To show every piece of material needed would not be practical as the plans would become so cluttered as to be unreadable. Therefore, the important points are the significant dimensions and the spacing of such items as studs, joists, and rafters. If sufficient care is taken in reading a set of plans, an accurate bill of materials can be determined. All explanatory notes should be carefully read as they are invaluable in preparing a correct estimate and often can clarify any question that arises. To aid in gathering this bill of materials a form was developed that listed the basic parts of a building together with the information required for each such part. Many prepared plans of farm structures sold by commercial firms already have a bill of material computed and therefore, the estimator is relieved of this tedious job. The important point to remember is that accuracy and speed do not go together in making an estimate.

Once a bill of materials has been calculated the material and labor cost can then be determined. The material cost can be obtained merely by knowing the unit price of all listed items. Labor hours first must be computed for all materials erected and these then converted to cost. To do this the appropriate figure must be used from the Labor Factor table.

The estimating form was developed to aid the beginning estimator in computing the above calculations.

Some of the possible uses for estimate are as follows:

1. To obtain the approximate cost of a building.

2. To compare one method of construction against another.

3. To determine the value of a farmer's time, that is to find out how much his time is worth in terms of hired labor.

4. To compare farm built structures with pre-fabricated buildings. This is quite important today since many people believe that farm built structures are uneconomical.

5. To see where there may be a chance to reduce construction costs by altering plans or changing materials.

The method developed by this investigation appears to have good possibilities. Unfortunately time was limited so as to make large accumulation of data impossible; but if the investigation is continued and expanded, gradually more representative data can be compiled. It is believed, however, that the method of detailed estimating has already proven itself satisfactory, and even though there might be modifications at a later date, the basic method should be used.

ACKNOWLEDGMENT

The author wishes to express his appreciation to Professor F. C. Fenton, Head of the Department of Agricultural Engineering, for his suggestions and direction; to Edwin R. Chubbuck for his thoughtful and timely assistance throughout the project; and to the many farmers, contractors, and other persons without whose help this investigation would not have been possible.

LITERATURE CITED

(1) Barnes, Frank E.
Estimating building costs. New York: McGraw-Hill, 656 p. 1950.

(2) Barre, H. J., and L. L. Sammet.
Farm structures. New York: John Wiley, 650 p. 1950.

(3) Carter, Deane G., and W. A. Foster.
Farm buildings. New York: John Wiley, 404 p. 1941.

(4) Carter, Deane G.
Case studies in low-cost housing. Agricultural Engineering. 22: 427-428. December, 1941.

(5) Carter, Deane G.
The cost of farm buildings. Agricultural Engineering. 11: 190. May, 1930.

(6) Dingman, Charles F.
Estimating building costs. New York: McGraw-Hill, 401 p. 1944.

(7) Neubauer, L. W.
Syllabus on farm structures. unpublished.

(8) Pulver, H. E.
Construction estimates and costs. New York: McGraw-Hill, 653 p. 1947.

(9) Strahan, J. L.
Shall the farmer be encouraged to continue doing his own construction work. Agricultural Engineering. 26: 25. January, 1945.

(10) Townsend, Gilbert, Ralph J. Dalzell, and James McKinney.
How to estimate for the building trade. Chicago: American Technical Society. 663 p. 1947.

(11) Underwood, George.
House construction costs. New York: McGraw-Hill, 314 p. 1950.

(12) Wooley, John C.
Farm buildings. New York: McGraw-Hill, 354 p. 1946.

(13) Wooley, John C., and R. P. Beasley.
Farm appraisal. Mo. Agr. Expt. Sta. Cir. 213. 1941.

(14) Anonymous.
The farm book. Published by the West Coast Woods, Portland, Ore. 1947.

A METHOD OF COST ANALYSIS
FOR FARM STRUCTURES

by

ALLAN ARCHIBALD MCKILLOP

B. S., University of California, 1950

AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agricultural Engineering

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1951

Probably the most important question facing any prospective builder is how much will the proposed structure costs. The question can be answered, in most cases, by the professional contractors whose business it is to know how to obtain an estimate. However, since a large share of farm structures are erected by farm labor, this experienced information is not available to farmers.

An investigation was undertaken to see if a simple, accurate method for an economic analysis of farm structures could be developed. The detailed estimating system seemed the most accurate and so was modified to apply to farm buildings. As this method entails knowing labor factors (man-hours to erect a unit amount of material) for each job element of a building, a major portion of the investigation was devoted to obtaining such factors.

After suitable factors had been determined, a form (see page 4) was developed whereby an estimate could be calculated knowing only the local prevailing prices of labor and of materials.

Finally several illustrative calculations were made to show the proper use of the form and to illustrate the following points:

1. Variation in different types of construction.
2. Variation between skilled and unskilled labor.
3. Variation in building costs in different sections of the state.

In order to get a true comparison between farm labor and skilled labor, the study was divided so as to obtain factors for both types of builders. Unskilled (or farm) labor data were gathered from information available on recently constructed farm structures; skilled labor data were obtained from professional builders. In each case corresponding figures were sought so as to make all data comparable. From these data a table (see page 4) was constructed showing the value of both types of labor. Each factor was expressed as a single figure. It did not seem feasible to set limits since high and low readings may have differed by a multiple of 5 or 6. Also, someone would eventually have to select an exact figure, and it was felt that one more familiar with the factors could make a better estimate.

The results, in general, follow the expected pattern of skilled labor being more efficient than unskilled labor. The apparent inconsistencies that occurred may be explained by one of the following reasons: (1) a farmer is in a hurry to finish a building while a skilled laborer does not worry about completion time; (2) some materials are used in large part on farm structures only, and therefore, a farmer is more familiar with their construction; (3) and, finally, the reversal of pattern occurred on those jobs that were more elementary in nature and required less skill in their performance.

The estimating form was evolved from the natural sequence followed in determining any estimate. To maintain simplicity yet not attain cumbersomeness, the form was prefaced by an instruction sheet. Therefore, only the actual calculations were included in the form proper.

The illustrative calculations gave the following results:

1. The pole type structure was much cheaper and required less man-hours to erect than the frame structure.

2. The difference between concrete block and frame construction was very small in both time and money.

3. Skilled labor can erect a building much faster than unskilled (or farm) labor.

4. The variation in costs over the eastern part of Kansas was not sufficient to show marked differences.

It should be remembered that these results obtained under 1 and 2 are for individual cases and no general conclusions can, therefore, be made.

Excerpt from Estimating Form:

Estimating Form Sheet 2

Building ______ Dairy Barn ______

A	B	C	D	E	F	G		H	K	L	M	N
Framing												
Class	Pieces or lin.ft.	Dimensions in x in x ft	Material Fbm: Amount needed	Material Fbm: Inclu. overage	Unit price	Material cost	Remarks	Lab.fact. mhrs/Fbm	Labor hours	Labor wage	Labor cost	Total cost
Sills and plates	___ lin. ft. ___ ___	___ x ___ ___ x ___ ___ x ___	___ ___ ___	___ ___ ___	___ ___ ___	___ ___ ___		___ ___ ___	___ ___ ___	___ ___ ___	___ ___ ___	___ ___ ___
Studs	___ pc. ___ pc.	___ x ___ x ___ ___ x ___ x ___	___ ___	___ ___	___ ___	___ ___		___ ___	___ ___	___ ___	___ ___	___ ___

Excerpts from Labor Factor Table:

Division	Class	Units	Skilled: Observations	Skilled: Factor	Unskilled: Observations	Unskilled: Factor	Remarks
Concrete	Mixing and placing	mhrs/cyd	8	2.7	49	2.3	Includes mixer and crew. Use for all concrete. Includes time for placing reinforcing.
Masonry	Concrete blocks	mhrs/block	26	0.091	12	0.111	
Carpentry	Wall framing	mhrs/Fbm	15	0.030	11	0.047	Includes studs, plates, headers, braces, girts.