DESIGNING A MATERIALS HANDLING SYSTEM

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The title of the paper should probably read "A Solution to a Problem *Involving* Materials Handling", because the handling of materials was not in itself the major objective. The problem was to develop a grain feeding system for a beef finishing farm in East central Alberta. The *major* objective was that the grain feeding be carried on at the lowest practical cost.

In dealing with production problems on farms, it is important to realize that each farm is different and that the solution obtained is determined by a set of conditions unique to the particular farm considered.

Some of the conditions imposed by this particular farm were these:

1.) The number of feeder cattle which were to be handled was limited by the amount of forage and grain which could be grown on the ¾ section farm. This condition distinguished this enterprise from another which might be limited in size by some other consideration such as the amount of labor available.

2.) Another condition was that the farm was located seven miles from a large town on a black-top highway.

3.) A one-ton truck with dump mechanism, a portable grain auger and an 8½" plate grinder were presently in use on the farm.

Figure 1 illustrates other features of the farmstead which influenced the feed handling system. These features will be noted as they become of importance to the operation involved.

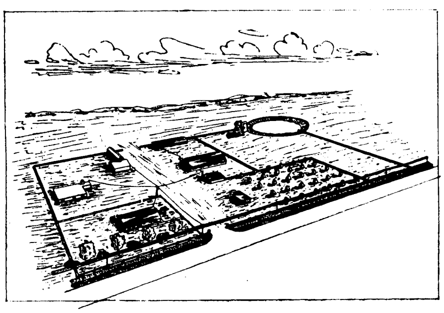


Figure 1. Present Farmstead Layout

Based upon the average grain and hay production on this farm over the past ten years, and from feeding figures obtained from the bulletin "Cattle Finishing in Alberta" (1) the feedlot was sized to accommodate 150 head of yearlings. Reference to this bulletin showed that a daily average of about 1800 pounds of grain would be eaten by these animals for 140 days.

Developing the Process

The overall problem of getting the whole grain from the granary to the feed bunks in the form of chop may be defined as a "Process". Figure 2

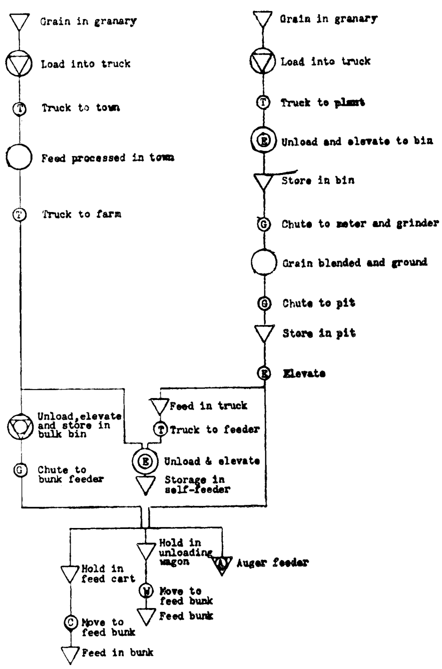


Figure 2. Process Chart

shows a "process chart" made up of alternative methods of completing this process. It can be seen at this point that no unique solution to the problem was evident. A solution was obtained by selection from the several alternatives. This is a general case in the solution of problems in the field of production. The imposition of boundary conditions reduces the number of variables, but even then there are usually more unknowns than there are equations.

Make or Buy Decisions

The first pair of alternatives involved a choice between farm grinding and custom grinding in the town seven miles distance. In order to make a decision on this point, costs were compared. A short hand system of cost analysis used widely in industry is the "Short Pay-off" method. Here, saving in direct operating cost must balance any difference in capital costs within the pay-off period, usually from one to five years. Figure 3 shows

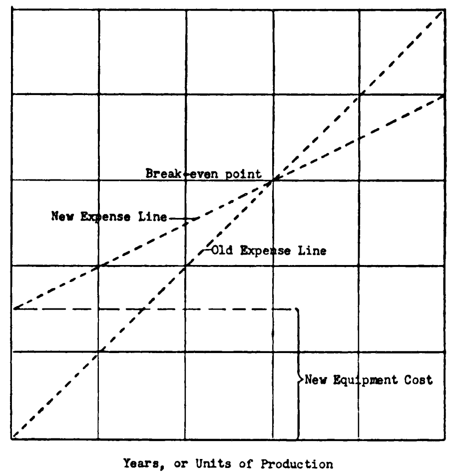


Figure 3. Break-even chart

a break-even chart illustrating the Short Pay-off method. Despite the simplicity of this method, it can serve as a useful guide in replacement and equipment purchase decisions providing the the pay-off period is carefully selected.

A more analytical approach is the modified MAPI (2) formula work sheet. A useful comparison for purposes of this paper was that for the class of equipment involved, application of the MAPI formula indicated decisions similar to those indicated by the Short Pay-off method using a five-year pay-off period. Decisions in this paper were based upon the Short pay-off method, using a five-year pay-off period. In applying this principle to farm grinding vs. custom feed preparation, the farm plant would be selected only if its capital cost plus operating cost for five years, was exceeded by the delivered cost of custom preparation of feed in a five-year period.

A Farm Grinding Plant

Minimum requirements for a feed preparation plant should be:

1.) that feeds can be mixed in desired proportions;

2.) quantities can be weighed, or alternately, measured volumetrically with provision for spot checking weight.

Figure 4 illustrates the equipment details of this proposed plant. A pro-

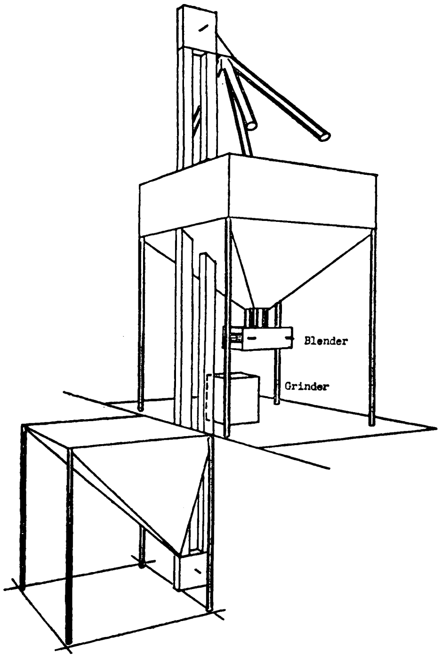


Figure 4. Farm Grinding plant

cess chart for the system would show 3 operations, 5 transportations, and 3 storages.

Lest the plant that was selected appear more elaborate than necessary, it should be pointed out that the minimum requirements as listed above are the difficult ones to meet. The fact that the plant required little hand labor was realized incidentally to achieving the primary objectives.

The heart of this grinding and handling plant was the elevator. A centrifugal discharge elevator was selected over an auger on the basis of the cost analysis. Details of this calculation are shown in Appendix A. The general operation of the plant is self-evident. It should be noted that a plant very similar in lay-out could have provided for grinding oats and barley or wheat separately, then blending them before feeding. The basis for selection was that the whole grain could be more readily handled from gravity bins than could ground feed. Simpler bin design resulted from the selected lay-out.

Economic Lot Size - Bulk Feed Bin

The alternative to farm grinding was to haul grain to the custom plant in town where it could be ground and mixed. The prepared feed could be then hauled back to the farm where it would be stored in a bulk feed bin, or possibly unloaded directly into a self feeder.

The total delivered cost of feed prepared in this manner was made up of three cost items:

1.) grinding cost,

2.) delivery cost,

3.) farm storage cost.

The sum of these three costs represents a variable total, depending upon batch or lot size. For some particular lot size, the unit cost will be at a minimum value. It is important to try for the most "economic lot size" whenever possible. The method of determining the economic lot size follows:

C_s = hauling cost per load
T = total yearly tonnage
N = tons per load
L = No. of loads $= \frac{T}{N}$
I = yearly storage cost per ton of storage provided.

Total cost of hauling and storing:

$$= N\ I + C_s\ L$$

$$= N\ I + C_s \frac{T}{N}$$

Taking the derivative with respect to N, and equating to O yields:

$$O = I - \frac{C_s\ T}{N^2}$$

from which the most economic lot size occurs when:

$$N = \frac{C_s\ T}{I}$$

It was assumed that the plant shown in Figure 4 represented lowest cost plant that would adequately perform the feed preparation task, and that the price quoted for commercially prepared feed represented the cost based upon economic lot size. A selection was made between these alternatives on the basis of a cost analysis.

This analysis is shown in Appendix B. Based upon the five-year short payoff method, building the farm plant was indicated. This represents a typical "Make-or-Buy" decision. It is interesting to note that a common rule in industry is *"Don't make until every possibility of buying has been exhausted"*. The previous decision should probably be reviewed in the light of this viewpoint.

Feeding Systems

At this point, with the mixed feed ready for consumption, a decision on the method of feeding had to be made. There were two broad courses open: full feeding using self-feeders, or limited feeding employing feed bunks.

Bunk Feeders

Three possible methods follow:
1.) auger, or drag type bunk feeder,
2.) unloading wagon,
3.) hand operated cart.

These three were selected for the following reasons:

1.) they are practicable within the limits imposed by the location of existing facilities,

2.) both the auger feeder and unloading wagon are standard items of equipment,

3.) the slope of the feed lot would aid in moving the loaded hand cart.

There were no unique features involved in either the auger system or the unloading wagon. Both have proven to be mechanically sound methods of handling ground feed. In making the auger selection, possible future changes in the hay-feeding process were considered. At that time, hay was handled long by means of sweep-stacker, custom stack mover, and grapple fork for filling the bunks. Should future developments lead to lower cost handling of cut hay, combined hay and grain feeding could be considered. The multi-purpose auger was selected over tube feeders on this basis.

The idea of a hand operated cart is certainly not new. The problem here, however, was that a cart carrying up to 1,000 pounds of feed would be too heavy to handle, and if more than one trip was required to a single yard, the more enterprising animals would probably get more than their share of grain. By dividing the feedlot in two parts, the cart was reduced to half the size. This reduction in size coupled with the slope to the yard of one foot in a hundred made this size of cart entirely practicable.

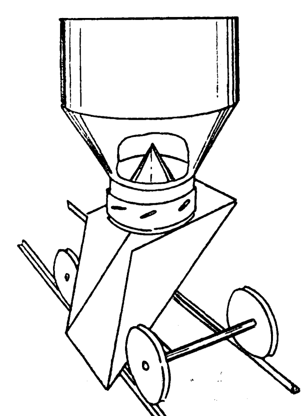


Figure 5. Hand Feed Cart

The inclusion of a feed cart in this discussion violates one of the principles of materials handling which is "use standard items of equipment whenever possible". However, this particular cart shown in Figure 5 could be readily constructed, and should last indefinitely. The cart employes a hopper design featuring the principle of expanding flow to assist in emptying.

Cost calculations for these three alternate methods of limited feeding are shown in Appendix C. On the basis of these calculations, the hand cart was selected as the alternative to self feeding.

Self Feeders

Three grain self-feeders adapted from a portable granary (3) were required to provide 1 linear foot of bunk for each animal. It was considered for the purpose of this paper that these feeders would be constructed from existing granaries and would be filled using equipment already on the farm.

Selection from Alternative Feeding Systems

Based upon feed requirements as listed in, "Cattle Finishing in Alberta", and upon hay and grain yields for this farm, a saving of $235.00 per year could be realized by using a method of limited feeding as against full feeding, providing, of course, that the cost of feeding was the same in both cases. The calculations involved in arriving at this figure are shown in Appendix D.

This sum of $235.00 represents the saving in *direct cost* by using the principle of limited feeding over full feeding. Based on the five-year payoff period, any net *capital cost* of less than 5 $\times$ $235.00 = $1,175.00, in favor of self-feeding would favor the adoption of the limited feeding system; the lower this net capital cost figure, the greater the saving.

Appendix D contains a cost analysis of the self-feeders and the alternative provided by the feed-cart and bunks. On the basis of this analysis, the feed-cart and bunk was selected. It is interesting to note that all three limited feeding methods have pay-off periods of less than 5 years.

The complete grain handling was at this point established. A farm processing plant, coupled with a simple feed bunk system was selected as a solution to the materials handling problem.

Operating Factors - Predetermind Man and Machine Times

It is usually desirable to establish the time required for any proposed process to be run through. This aspect is of prime importance in systems where the operator's time may be the limiting factor, and it is of at least some significance in almost all cases. For example, cost of automatic controls is generally based upon the saving in labor costs which may be realized. Labor cost can be a misleading item however, when assessed by the amount of work in hours which may be performed by men working eight-hour days. It may be noted that a reduction in hours of work from 14 to 13 results in no cost saving whatsoever, while reduction from 9 to 8 eliminates one shift and reduces the cost of labor by 50%. This fact points up that "hourly" costs of labor may be a misleading term. The question is frequently answered more accurately by considering the "daily" cost of labor.

In the problem at hand, the operator was chiefly concerned with the beef-feeding enterprise. Considering the other work that was included in this enterprise, a figure of about three hours per day was thought not to be excessive for the feed handling process. A time study of this process served chiefly to establish whether or not this figure could be achieved.

Industry, faced with predetermining operating times, has developed techniques which should be of interest to agriculture. "Man and Machine" charts are useful in suggesting areas for improvement. Several predetermined time study systems are in use in industry. By applying established times to operations made up of normal body motions, accurate times may be forecast. One of these systems is the MTM (4), or Method-Time-Measurement system.

Applications of 'Man and Machine' charts, and predetermined time techniques to the operations of getting a load of grain, grinding grain for one feeding, and filling the feed bunks, gave an average daily labor forecast of 108 minutes. These would normally constitute all of the operations involved in the grain handling process. The addition of automatic controls to the grinding equipment could eliminate a further 20 minutes of man-time. Since 108 minutes fell well below the limiting figure of three hours per day it was considered that the addition of automatic controls could not be justified at that time.

APPENDIX A

Cost Analysis — Centrifugal Discharge Vs. Auger Elevator

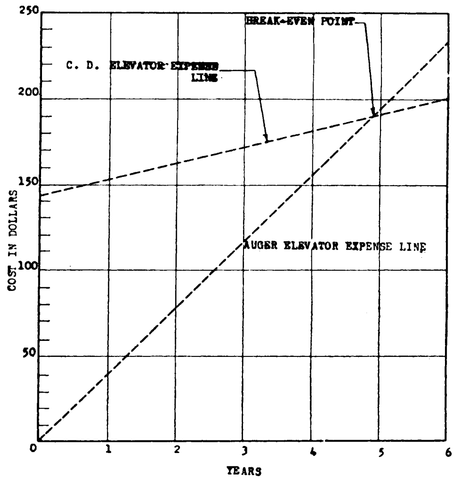
Capital Cost (purchase Cost of Equipment)

4" Auger System	$300.32
Centrifugal Discharge Elevator	443.00
Net Capital cost favoring auger	$142.68

Operating Cost Per Year

4" Auger System	$ 38.80
Centrifugal Discharge Elevator	9.70
Net yearly operating cost favoring Centrifugal Discharge Elevator	$ 29.10

Pay-off period — $\frac{142.68}{29.10}$ = 4.9 yrs.



APPENDIX B

Capital Cost

Farm Plant:

1) for self feeder	$1,730.00
2) for limited feeding	1,430.00
Commercial processing	0.00

Operating or processing yearly Cost

Farm Plant:

1) for self feeder	66.00
2) for limited feeding	55.00

Commercial processing:

1) for self feeder	510.00
2) for limited feeding	425.00

Pay-off period for limited feeding

$$\frac{(1430.00 - 0.00)}{(425.00 - 55.00)} = 3.86 \text{ years}$$

Pay-off period for self feeding

$$\frac{(1730.00 - 0.00)}{(510.00 - 66.00)} = 3.90 \text{ years}$$

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APPENDIX C

Capital Cost

Auger bunk feeder	$1,427.50
Unloading wagon system	583.00
Hand feed cart system	423.00

Operating Cost Per year

Auger bunk feeder	7.50
Unloading wagon	24.00
Feed Cart	0.00

1.) Pay-off period for auger vs. unloading wagon:

$$\frac{(1427.50 - 583.00)}{(24.00 - 7.50)} = 57.5 \text{ years}$$

2.) Hand cart vs. onloading wagon

The hand cart system, having both a lower first cost and operating cost, is clearly indicated as the best selection.

APPENDIX D

Capital Cost

Self feeder	
Modifications to 3 existing portable granaries	$ 300.00
Feed cart system (Appendix C)	423.00
Net capital cost favoring self feeder	123.00

Yearly Feed Costs

Limited feeding system	
Grain (Appendix B)	3,865.00
Roughage 112 Tons at $17.50/Ton	1,960.00
	$5,825.00
Self feeding system	
Grain (Appendix B)	4,625.00
Roughage 82 Tons (1) at $17.50/Ton	1,435.00
	$6,060.00
Net feed cost favoring limited feeding	235.00

Pay-off period $\frac{123}{235} = \frac{1}{2}$ year

For additional comparisons:

1.) for unloading wagon

Pay-off period =

$$\frac{(583 - 300)}{(235 - 24)} = 1.35 \text{ years}$$

2.) for auger bunk feeder

Pay-off period =

$$\frac{(1,427.50 - 300)}{(235 - 7.50)} = 4.95 \text{ years}$$

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economic advantage of such a program. If the economics are not favorable, then inducements must be added, possibly through construction or financial aid. This is another portion of the program that will require a great number of years to accomplish.

Research activities must keep abreast or ahead of watershed development work. The development of techniques and methods and the compilation and analysis of research information will need priority in an adequate program of water use and conservation.

Experience has shown that there are two distinct phases to a water development program, the engineering and the agronomic which must be brought together. It is virtually impossible to deal with watershed development or with research in hydrology solely in terms of one or the other. Close co-operation is required to develop to the fullest the potentials of any watershed. Satisfactorily designed structures are but half the job, compatable crops and cropping practices are necessary to complete the picture. It is only through such co-operation that the project economics can become favorable.

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