Evaluation of farm buildings as a factor in agricultural production

Frank Bristol Lanham

Iowa State College

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EVALUATION OF FARM BUILDINGS AS A FACTOR IN AGRICULTURAL PRODUCTION

by

Frank Bristol Lanham

A Dissertation Submitted to the Graduate Faculty in Partial Fulfillment of The Requirements for the Degree of DOCTOR OF PHILOSOPHY

Major Subjects: Agricultural Engineering Agricultural Economics

Approved:

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Iowa State College

1952
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INTRODUCTION

From earliest recorded history, man has considered shelter essential to the production of crops and livestock. The Bible records the birth of Jesus Christ as taking place in a stable used for the housing of farm animals. Throughout the centuries farm buildings have remained as a factor in practically all types of agricultural production.

In certain sections of Europe, notably certain areas of France and the Scandinavian countries, livestock and feed shelters were oftentimes attached to family living quarters by means of alleys and passageways of various kinds. By this arrangement the attendant was not exposed to the elements in caring for the livestock and stored crops and his food and feed crops were stored near at hand for convenience and constant supervision and control.

The early American pioneer considered farm buildings essential from the standpoint of protection from wild animals and savages as well as the elements of the weather. Farm buildings followed quickly or were simultaneously developed with protection for the pioneer and his family.

Prior to about 1910, farm buildings were included in the bulk capital requirements for farming and little effort was made to measure and evaluate the input with reference to
output of the farm. As the twentieth century has advanced, however, the keynote has been efficient use and allocation of resources, and the evaluation of farm buildings as a factor in agricultural production has become a topic of increasing importance to the farmer and to the agricultural technologist as they have cooperated in an effort to increase the efficiency of American agriculture.

Among the characteristics of the farm building input the following seem pertinent:

1. In a breakdown of farm operating costs, charges to service buildings are small as compared with such inputs as feed and labor.

2. Buildings are extremely demanding on the farmer's capital. If capital is a scarce means, as it so frequently is, the building input immediately takes on significance.

3. Expenditures for buildings in the majority of cases represent fixed costs of operation.

4. With the exception of relatively small buildings, the building input is non-transportable from farm to farm.

5. The nature of the input is of such a nature as to present special problems in a society containing a high percentage of itinerant, agricultural operators.

Output characteristics of the farm building investment include such varied factors as increased labor efficiency; contributions to higher quality crops, livestock, and food
products; increased revenue through the ability to hold products for higher prices and more orderly marketing; advertising value; and personal satisfaction of the owner. Clearly, farm building expenditures fall both within the production and consumption categories of economic analyses.

Although the literature is extensively supplied with contributions pointing to the importance of farm buildings as a factor in agricultural production, little evidence exists that a concerted effort has been made to analyze input-output relationships in light of current economic theory. Until suitable theoretical models are developed, progress in analyzing this production factor will be hampered by doubt, controversy, and speculation. It is toward the end of clarifying and delineating appropriate theory relative to farm buildings as a factor in agricultural production that this work is directed. Practical applications will be demonstrated and evidence submitted as to the applicability of the theory to field studies. It is on these bases that the present study is justified.
REVIEW OF LITERATURE

Magnitude of the Farm Building Investment

The magnitude of the farm building investment in American agriculture has been cited by several investigators. Because of the scattered nature of farm buildings the aggregate national investment is seldomly appreciated, amounting in 1940 to $10,405,435,796 (48). Maintenance and repair of the national farm building plant in 1950 involved an expenditure of 628 million dollars (13). Of this total approximately 38 per cent was expended for service buildings. New construction in the same year amounted to approximately twice the maintenance and repair figure or 1,173 million dollars, divided about equally between farm houses and service buildings. Warren (50) stated that on 578 farms surveyed in Livingston County, New York, barns represented 19 per cent of the total capital investment on small farms, or $164 per animal unit housed, and on larger farms 11 per cent, or $50 per animal unit.

Stressing the importance of the relation of capital invested in farm buildings to the limited knowledge now available regarding the resultant production function of buildings, Agricultural Engineering (3, p. 139), commented editorially as follows:
To restate the situation in other words, farmers are making their second largest investment upon only the most general knowledge of how and how much that investment may contribute to the overall efficiency of their farms.

Farm Building Expenditures Related to Farm Values

Relating the expenditures for buildings to farm values, Boss and Pond (9) suggested that relatively small investments in farm buildings are likely to be fully recoverable in the sale price of the farm or may, in certain instances, add more to the value than the expenditure for the building represents. However, a point is soon reached where the sale price of the farm does not increase by corresponding amounts invested in new building construction. These writers reported that on many farms the point has been reached where additional expenditures for buildings add very little, if anything, to the sale value of the farm.

Ezekiel (18), surveying 422 farms in a Southeastern Pennsylvania County, compared the value of dairy and other buildings in dollars per acre to the deviation of farm values from the average value per acre, other factors being the same. Results are based on data collected from April 1, 1922 to March 31, 1923. A portion of his results are shown in Figure 1. Based on the average, the investment in dairy buildings amounted to approximately $41.00 and other buildings to $12.25 per acre.
Wiecking (54) continued the work of Ezekiel in 1927 and early 1928 in several mid-western states. Certain of his data are shown in Figure 2. The point of intersection between the lines showing farm building investment, depreciated values, dollars per acre, and increase in sale value of farm property, dollars per acre, occurs at a building investment figure of $49.00 per acre. Results of the studies made by Wiecking and Ezekiel, when reduced to a comparable price level, indicate general agreement as to the influence of the farm building investment on the sale value of farm property.

Haas (22) attacked the problem of determining the influence of building improvements on the sale price of farms by developing a multiple correlation of five factors; (1) location of farm, (2) present worth of buildings, (3) land classification index, (4) productivity of the soil, and (5) distance to market. He reported from the solution of his statistical equation that based on the sales records of 160 farms in Blue Earth County, Minnesota, $1.07 was added to the sale value of farms for each dollar invested in buildings.

Nature of Farm Building Returns

The literature is plentifully supplied with contributions as to the nature of farm building returns. Wooley (56)
Figure 1. Relation Between the Value of Farm Buildings per Acre and the Deviation of Farm Value per Acre from the Average, Other Factors Being the Same, on 422 Southeastern Pennsylvania Farms, 1922-23.
Increased Sales Value

Building Investment

Figure 2. Influence of Buildings upon Farm Property Values
divided expected returns into four categories as follows: (1) increased sales value of farm, (2) greater net return from enterprises, (3) increase of credit facilities extended the farmer, and (4) personal satisfaction of farmer. Ezekiel (18) concluded that cows adequately and comfortably housed was a major factor in profitable dairy farming.

White (51) stated that based on a study made by the agricultural engineering and farm management departments of the University of Missouri, high present worth of farm buildings was closely correlated with efficient use of labor. White and Neubauer (52) concluded that as the farm operator's labor earnings decreased there was a trend for the value in the investment in farm buildings to adjust downward.

Hanson (23) reported a serious lack of good information relative to the true value of a farm building in agricultural production. This writer suggested present information is not sufficient to allow evaluation of farm building outputs under different farming types and management practices. Curry and Giese (15) expressed the belief that until the value of farm buildings could be more definitely established, their contribution could best be measured in terms of savings in, and increased efficiency of, farm labor.

Swenehart (46, pp. 233-4) posed the question of farm versus industrial building efficiency in these terms:
... Why do loan agencies, even the farmer's own federal land bank, loan on a basis of 20 per cent of the insurable physical value of farm buildings while in Madison, a city of some 50,000 population, a new theater is being financed by a loan of $475,000 on a valuation of $807,000 ...? Does the difference between 60 per cent or let us say roughly 50 per cent, of the value as compared with 20 per cent of the value in case of farm buildings represent the difference in efficiency between farm buildings and industrial and business buildings?

There is some evidence suggesting that as agricultural production is accelerated farms tend to demand higher service from farm buildings. In periods of prosperity emphasis is placed on farm construction, repair and maintenance. Conversely as Carter (11) reported, when farm prices are low expenditures for buildings are meager; in fact, insufficient to offset depreciation and repairs necessary to maintain the buildings in a constant condition.

Factors Causing Variation in Farm Building Investment

Wooley (56) enumerated the factors causing variation in investment in farm buildings as follows:

1. Appreciation of farmer for good buildings
2. Type of farming
3. Size of farm
4. Distance from market
5. Productivity of the land
6. Number of crop acres
7. Number of animals kept
8. Quality of animals
9. Value of the farm

Dual Nature of Needed Research in the Farm Structures Field

A review of the literature forcibly reveals a lack of information and considerable controversy pertaining to farm buildings from two major standpoints:

1. Optimum environmental conditions for crops or livestock housed
2. Optimum economic balance relative to such factors as first cost, annual cost, depreciation, years of useful life, flexibility, farmstead arrangement, and labor efficiency

Swenehart (46, p. 235) emphasized these two points as follows:

The most constructive suggestion, however, is that farm buildings men take the responsibility for research along these lines, particularly associating this research with animal production on one hand and agricultural economics on the other. It is admittedly easy to construct a building which will be strong enough, that will meet space requirements, that will have a given number of windows and can be covered with a certain kind of paint. It can have all sorts of details worked out from an engineering standpoint, but if these details do not contribute to the increased production of a cow or other animal housed, or if they fail to meet the economic requirements, that is, production per unit of cost, it may be a failure.

Economic questions have developed as more and more emphasis has been placed on efficiency of agricultural production. If proper resource allocation in production is to
be assured, farm buildings must be analyzed and current
economic theory applied, either in existing or adapted form,
toward the determination of input-output relationships.
That the problem involves joint agricultural engineering-
agricultural economic implications has been recognized.

Commenting editorially on this subject, Agricultural
Engineering (36, p. 251), emphasized the engineering-economic
relationship:

Gradually but none the less surely engineers in
all fields of activity are recognizing the in-
separability of engineering and economics. In
recent years agricultural engineers have come
more and more to appreciate that the true develop-
ment of engineering as applied to agriculture is
based primarily on its economic relationships.

Dr. Dexter S. Kimball (1, p. 267), former dean of the
College of Engineering, Cornell University, writing in
Agricultural Engineering, stressed the same relationship in
stating:

The engineer of the new day will need to know
economics both in theory and in practice and he
will need to be able to stand up on his feet
and talk economics.

Again editorially Agricultural Engineering (2, p. 35)
commented:

... a lack of economic data is the limiting factor
in progress on the farm structures side of applying
engineering to agriculture.

It is evident ... that agricultural engineering
work in farm structures lacks a scientific as
well as an economic basis for progress.
Economic Considerations

**Initial cost**

Hanson (23) pointed out the importance of low initial cost of farm buildings in relation to the capital position of the farmer. He posed the question as to why the present operator should pay interest on the capital required to construct a highly permanent building when the structure is likely to remain in use for years after the operator is gone. This writer suggested that measures should be taken to provide efficient shelter at a smaller initial cost and a comparable annual cost even if something has to be sacrificed in terms of the life of the structure. Boss and Pond (9) suggested that high initial costs of farm buildings often-times resulted from a combination production-consumption expenditure on the part of the farmer. The latter is motivated perhaps by several factors but, in general, money spent in this manner may be said to give equal or greater satisfaction to the farmer and his family than when devoted to other uses. These writers pointed out that buildings constructed on the basis of consumption outlays could not be used as collateral or converted into cash for the payment of interest and principal to the creditor.

Hart (25, p. 398) in 1939 stated that the initial cost
of farm buildings was near prohibitive. His advice to young farmers was to "buy a farm and get the buildings thrown in". He reasoned that building costs were invariably reflected in the sale value of the farm in a manner unfavorable to the seller. He concluded that the relatively high price of construction as compared with the low price of farm products ruled out the possibilities of building based on any sound economic reasoning.

Strahon (45, p. 8) analyzed the problem of initial costs as follows:

Even the most rabid cost cutter of them all will admit, I think, that some cost in buildings must be allowed. Farmers quite definitely cannot get along with zero costs. And, on the other hand, even the most extreme advocate of "fancy" construction will recognize that there is a limit beyond which it is absurd to go in spending money for farm construction. Very well, the low limit is something more than nothing and the high limit is easily recognized by all. Somewhere between these two extremes is a level of expenditure that is rational and reasonable.

Miller (39) pointed out that the only source, aside from an outright gift, which the farmer has for funds with which to build is from the already meager farm income. Hanson (23) emphasized the tie-up of 20 to 50 per cent or more of the farmer's total farm investment which often the buildings represent.

Annual cost

Annual farm building costs are generally considered to
consist of depreciation, interest, maintenance and repair, insurance, and taxes. Swenehart (46) reported in Wisconsin the annual gross income from the dairy business to be 225 million dollars and the annual costs attributable to buildings to range between 50 and 70 million dollars. This, he emphasized, represented two and one-half months' production of all Wisconsin cows or 10 to 12 cents per pound of butterfat. This overhead being strictly a fixed cost must be paid before feed, cost of the herd, labor, and profit. Swenehart concluded that the labor saved by the buildings could not be enough to justify the overhead.

Depreciation

Wooley (56, p. 9), in his fundamental work on depreciation of farm buildings, suggested the straight line method of depreciation as most suitable for investigations in this field. His reasoning in part was as follows:

... the service rendered by buildings during their life does not vary greatly with age. They are not built in most cases with a view of having a resale value, but are constructed for the service they will render in increasing production, saving feed, protecting health or improving the quality of products.

Long-lived versus short-lived buildings

Boss (10, pp. 63-4) believed it inadvisable to build short-lived buildings. He reported that farm buildings should be constructed to last for at least 100 years and
serve three or four generations. Boss continues:

Most of the farming sections of the United States have gone through the pioneer days, and we have reached a period of time when farm building should be standardized so far as general construction is concerned and planned with proper regard to economic returns.

......

History shows that our barns have about the same development as houses, except that some of the first ones were made from poles. ...... These lasted not to exceed twenty-five years and were replaced with lightly constructed frame barns lasting about fifty years. These should eventually be replaced with barns of more modern construction ...... which should give 100 or more years of service and add a great deal to the pleasure and satisfaction of its owners.

......

In the United States we have now reached a period of time where it is possible and desirable to build farm structures of a substantial character having a life of 100 years or more.

......

It is of course obvious that it is impossible to make an economic analysis of farm buildings covering the past 100 years as the prices for farm products are not stable and data is not available for such a purpose. Neither is it possible to predict what the next 100 years will bring forth. However, we have had farm buildings for more than 100 years, and we are safe in assuming that we will need them for at least that long in the future. Farm prices may go up or they may go down, but time goes on ......

......

It must be recognized that it is not possible to make sufficient profit on farm products to pay for new buildings in a few years' time, and to be profitable, buildings should be erected that will last over a long period of time, 50 to 100 years at least.

Compared with European standards very few American farm buildings may be considered permanent. Commenting on this editorially, Agricultural Engineering (4, p. 291), pointed
out that although sentimental homage may be paid to the
longevity of European farm structures, it is a definite ad-
antage to American agriculture that its buildings are short-
lived. The writer continued that we may have done too much
of the temporary although the relatively short-lived build-
ings have given the American farmer a relatively modern
place in which to live and work while the 500-year-old
European buildings have been obsolete for the last 450 years
of their life. The editor continued:

... they [farm buildings] are parts of working
units. As the systems of livestock management
or crop handling which they embody advance, they
become obsolete. As such systems in the future
become more complex, or at least more complete,
and their advance more rapid, building obsolescence
will be more and more an economic reality.

Numerous other writers and investigators have recom-
mended buildings of shorter life as better adapted to the
dynamic developments within American agriculture. Ekblaw
(16) stated that permanency should be defined strictly in
terms of construction which can be expected to exist without
major repair or maintenance until obsolescence has driven it
into the discard.

**Flexibility**

Closely associated with longevity is the matter of
flexibility or the ability to adapt a single building or
group of buildings to different enterprises as changes become
desirable from the standpoint of maximizing farm income. Wichers (53, p. 81) emphasized the dynamic aspect of agriculture when he stated:

It is very human to do things in the manner in which we have been taught. Yet we know that in this material universe change is the only constant element. It is interesting to watch the development of various industries, farming being no exception, and note the perpetual change that is taking place on all sides.

Benitt (7, p. 306) stressed the desirability of a flexible farm building layout as follows:

A characteristic of some farm structures is the inflexibility of use. Take the modern dairy barn, for example, with concrete mangers and gutters, stanchions . . . . It does not lend itself to any other use. It cannot be used for horses, or sheep, or hogs. Once such a barn is built you are doomed to stay in the dairy business for a generation or two at least. You may choose not to have milk cows, but your overhead cost is there nevertheless. To remodel such a barn would be quite costly.

We need to recognize also the changing character of production. Within the memory of most of us is the time when butter and eggs were relatively high priced in winter and cheap in summer. While there is still a price disparity, the difference is much smaller and it is for a much shorter time. Am I too fantastic to suggest that some producers of dairy products might have a higher income if their herds were pointed for heavy production during the spring and summer and "roughed" through the winter? The cost of shelter and care could be materially reduced under such a system of herd management.

Pinches (40, p. 463) stressed the advantages of flexibility when he wrote as follows:

... recent years have brought change and fluidity into the agricultural situation everywhere . . . .
All these factors call for greater flexibility in farmers' plans at the same time that buildings are becoming less flexible in design. . . . The necessary shifting can be done fairly easily in some types of agriculture, but in those types most closely associated with a large development of farm buildings, as usually developed, and the large investment in them often "freezes" the possible activity on a particular farm.

Hazen (26), Curry and Giese (15), and Carter (12) recognized and called attention to the importance of flexibility. Heady (39) stressed flexibility in farm buildings in conjunction with a general farm plan incorporating features making it adaptable to change. In a second paper Heady (30) analyzed uncertainty in market relations and resource allocation in the short-run farm plan. The latter paper contained certain aspects of theory relative to the flexible versus the inflexible plant.

Hart (24, p. 10) stressed the importance of including flexibility in all phases of economic planning. He stated, "We need a scheme of things in which possibilities of change through time are recognized."

Arrangement of farmstead

The arrangement of farm buildings to form the farmstead obviously has an important influence on the efficiency with which buildings contribute to the farm operation. Ives (32, p. 35) was critical of the arrangements found on many American farms. He wrote as follows:
It is safe to say that a large proportion of American farm building groups are the result of accident or force of circumstances imposed by thoughtless ancestors rather than a studied plan based on economic and climatic conditions. When one looks at some groups he is almost forced to believe that the buildings were located in a particular place because the farmer, driving in with a load of lumber, had got stuck in the mud and built where he was forced to unload.

**Contribution of farm buildings to increased labor efficiency**

In evaluating the contribution of farm buildings as labor-saving devices, Curry and Giese (15, p. 357) wrote as follows:

To attain and retain parity with industry the farmer must make and continue to make comparable improvements in labor efficiency. The physical volume of industrial production per worker has increased since 1900 at the compound rate of about 1-3/4 per cent per year. If the life expectancy of buildings is placed at 40 to 60 years, the farmer must ultimately attain within those buildings a labor efficiency two to three times the initial rate. To meet these requirements, buildings adapted to continuous alteration rather than periodic remodeling are essential.

Commenting editorially on the possibilities of buildings being more efficient contributors to farm labor efficiency, *Agricultural Engineering* (5, p. 279) stated:

How many of us...sense the opportunity lying dormant in the fact that in pork production labor costs three times as much as housing and equipment? In dairying, where the ratio is nearly six to one, a reduction of 17 per cent in labor requirement would justify an increase of 100 per cent in the housing and equipment cost.
Johnson, et al. (34) called attention to the fact that an average of approximately one-third of all farm work is done in and around buildings. This percentage varies widely with the nature of the enterprise, being as high as 80 per cent for poultry and dairy cows, and as low as 2 per cent for corn and small grains. These writers gave the percentages shown in Table I for other enterprises.

Table I

Per Cent of Total Work Done In and About Buildings for Different Farm Enterprises

<table>
<thead>
<tr>
<th>Enterprise</th>
<th>Per cent of total work done in and about buildings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hay</td>
<td>4</td>
</tr>
<tr>
<td>Potatoes</td>
<td>8</td>
</tr>
<tr>
<td>Tobacco</td>
<td>40</td>
</tr>
<tr>
<td>Sheep and lambs</td>
<td>20</td>
</tr>
<tr>
<td>Beef cattle and calves</td>
<td>30</td>
</tr>
<tr>
<td>Hogs</td>
<td>40</td>
</tr>
<tr>
<td>Horses and mules</td>
<td>70</td>
</tr>
<tr>
<td>Farm maintenance and equipment repair</td>
<td>45</td>
</tr>
</tbody>
</table>

1Taken from Johnson, et al. (34, p. 142)

Goodsell (21) reported labor efficiency in and about buildings not to have kept pace with that utilized in field operations. The writer presented the data contained in Table II to support his contention.
Table II

Man Labor Utilized in the Production of Crops and Livestock, Typical Cash Grain Farms in the Corn Belt, 1910-14 and 1938-42

<table>
<thead>
<tr>
<th>Crop</th>
<th>Hours labor required</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1910-14</td>
<td>1938-42</td>
</tr>
<tr>
<td>Corn per acre</td>
<td>19.5</td>
<td>10.3</td>
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<tr>
<td>Wheat per acre</td>
<td>13.4</td>
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<tr>
<td>Oats per acre</td>
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</tr>
<tr>
<td>Mixed hay per acre</td>
<td>11.0</td>
<td>8.0</td>
</tr>
</tbody>
</table>

| Livestock            |         |         |
|----------------------|---------|
| Hogs per 100 lb.     | 3.7     | 3.3     | 11% decrease |
| Stock cattle per head| 25.0    | 25.0    | No change   |
| Laying hens per 100  | 160.0   | 160.0   | No change   |
| Milking cows per head| 108.0   | 114.0   | 5% increase |

1 Adapted from Goodsell (21, p. 20)

Giese (19, p. 565) effectively stressed the relation of farm buildings to the possibility of increased labor efficiency on the farm. He stated:

The great advance in mechanization of agricultural operation has not been matched by similar improvements in buildings. We are advised that nearly 50 per cent of a farmer's time is spent in and around his buildings. This percentage, of course, becomes higher if the time required for field operations is greatly reduced while that in the buildings remains approximately the same as it was years ago.... Not only may the building affect the labor efficiency on the farm, but it may have a considerable influence on production of products such as milk or eggs, both in quality and quantity, .... What is then to be our measuring stick for buildings?
CHARACTERISTICS OF THE FARM STRUCTURES FIELD

As indicated in the preceding section, any analysis of farm structures as a production factor in agriculture embraces two separate but closely related fields, agricultural economics and agricultural engineering. It is the purpose of this section to point out certain aspects of the problem which either limit the analyses which follow or which are not dealt with directly in subsequent sections.

Factors in the Field of Agricultural Economics

Production versus consumption expenditures

The analyses which follow are based on the farm as a profit maximizing unit. The individual farmer is considered as an entrepreneur who, in one manner or another, commands certain inputs, transforms them in some way, and subsequently sells them with the purpose of making a profit.

This basic assumption is not intended to belittle or place in an insignificant light the consumption aspects of farm building expenditures which become so clearly apparent through field contacts with farmers. Aside from profit maximization, the following reasons are commonly given by the farm operator for the construction of a certain farm
building or group of buildings:

1. Imposing, spacious, and attractive buildings are testimonies to the farmer's success over time.

2. Absentee landlords state, in certain instances, that attractive, well-planned buildings assist in retaining a specific tenant which they desire or in retaining desirable tenants in general.

3. Buildings of pleasing appearance have a certain advertising value.

4. Long-lived buildings, pleasing in appearance, and conveniently arranged, tend to interest children in staying on the farm and hence become a factor in keeping the farm in the family.

5. Permanent type buildings provide more comfortable working conditions for the operator, his family, and his hired labor.

6. A natural desire exists for buildings equally as good as those of his neighbors.

These factors, and others of a like consumption expenditure nature, are recognized as important but are neglected in the analyses which follow. Farm buildings are treated as one of the firm's several inputs with a view of combining and processing these inputs in such a manner as to maximize profits over time from the farm operation.
Input-output relationships

The greatest single limitation in pressing to a successful conclusion an economic analysis of farm buildings as a factor in agricultural production centers about an almost total lack of knowledge of farm building input-output relationships. Empirical data are not only lacking but an exhaustive search of the literature indicates that very little effort has been, or is being, made toward arriving at these essential relationships. As the analysis continues this deficiency will become more apparent. Until it is possible to estimate with some accuracy the shape and general nature of the building production functions, speculation will continue to surround the contributions made by farm buildings as an input factor.

It is often assumed that the farmer has knowledge of the appropriate building production functions applicable to his operation. Further assumed is his knowledge of how technological innovations alter the input-output relationships for the particular enterprises in which he is engaged. That these assumptions are without foundation is attested to by the fact that such relationships are unknown and present a real challenge to agricultural specialists in the respective production fields involved.

Heady (23) pointed out that the farmer's primary interest rests in relationships between inputs or costs to
output or profits. Output-profit relationships are of interest to him only in an incidental manner inasmuch as his effective control lies in the inputs he elects to use rather than the output realized and the prices received for his production.

Little is known relative to the optimum division of the total building capital outlay between competing enterprises in such a manner as to equate marginal costs of building accommodations and marginal returns from the building investment placed in each enterprise. Specific information in this connection must necessarily await the more precise specification on the part of technologists as to the optimum environmental conditions which the building should provide for the maximum output of the several enterprises.

Expressed in equation form, $X_1, X_2, X_3, \ldots, X_n$, may be thought of as inputs to achieve a certain total production, $Q$. Then,

$$Q = f(X_1, X_2, X_3, \ldots, X_n)$$

If the farmer is engaged in three major competing enterprises, poultry, dairying, and hogs, $q', q'', q'''$, may be considered as representing, respectively, the production in these three enterprises. Allowing $X_3$ to represent the total building input, the optimum allocation of building funds between enterprises may be expressed as

$$\frac{\partial q'}{\partial X_3} = \frac{\partial q''}{\partial X_3} = \frac{\partial q'''}{\partial X_3}$$
It is recognized that the inherent long life, as well as inflexibility aspects of farm buildings, coupled with the changing farm production program over time, would tend to make this optimum allocation exceedingly difficult, if not impracticable, even though technical information were available relative to optimum environmental conditions to be provided for the housing of livestock and the storage of crops.

**Farm building costs**

The advisability of making substantial capital outlays for farm buildings has been questioned by some investigators on the basis that such expenditures contribute to the fixed costs of the farming operation. The implication has been that fixed costs are bad, *per se*. Only limited importance can be attached to such reasoning. The history of agriculture from the beginning of the present century has been one of increasing production and rising fixed costs. It would seem but logical that fixed costs must be viewed from the production level standpoint before being judged as good or bad.

Black, *et al.* (8) suggested that costs in the general agricultural field may have changed as shown in Figure 3. With limited output, costs in 1950 were higher than during the period 1900-1920. The effect of technological innovations has been, in general, to increase output and lower
Figure 3. Costs in Agriculture

Figure 4. Fixed Costs in Relation to Total Cost Curves
unit costs at stages of increased production and to raise, or keep constant, costs at lower levels of production.

In the case of the individual farmer, he may be faced with total cost curves as shown in Figure 4. Two curves, AB and CD, are shown, the first having a fixed cost of OA, and the latter a higher fixed cost of OC. At an output of OG the farmer would most advantageously operate along total cost curve AB incorporating a lower fixed cost. As input is increased to OF, however, his total cost is lower if operations are centered about curve CD involving the higher fixed cost.

Factors in the Field of Agricultural Engineering

Planning horizons

Inherent in the construction of farm buildings in the past has been the use of the structure for a specialized enterprise. The poultry house was constructed for the housing of poultry; a hog house for the housing of hogs; and so forth. The so-called general-purpose barn was general-purpose only in the sense of housing more than a single kind of livestock. Specific space allocations were made for the different types of animals, feeds, and other commodities to be housed.

If it is assumed that a given farm building or group of
buildings were designed and constructed to meet the requirements of a given production program under the supervision of a given operator, the chances would be that this building or group of buildings would serve the production programs of several subsequent operators prior to the expiration of the useful life of the structure or structures. This is evidenced by computations made, based on figures taken from the U. S. Census (47), indicating that in 1940 the average tenure period for all farm operators in the United States was less than 12 years and for tenant-operated farms the period was reduced to approximately five years. Curry and Giese (15, p. 357) emphasized this problem in stating:

Relatively few farms are so ideally suited to a specific production program that the requirements for buildings are independent of the personal tastes and abilities of the operator. The average building must render service for 4 operators with some change in types of production, management methods, and housing requirements accompanying each change of operator.

The obvious difficulties in intelligently extending planning horizons over the expected life span of a farm building, and their attendant inflexibility of use, have been important factors in farm buildings being considered, in certain instances, mere attachments to the land with little, tangible, productive worth. Wiecking (54) pointed out that in farm sales and leasing arrangements, oftentimes only casual regard was given to farm buildings in light of the production program which the prospective purchaser or
leaseholder had in mind for immediate development or for the ultimate program which he proposed to develop over time.

It is most common on Iowa farms to find hogs being produced in general-purpose barns in areas originally intended, for example, for horses. Remodeling will have been in some instances accomplished. However, the hypothesis is advanced that over the expected useful life span of a long-lived farm building, the structure, in a great number of instances, is used for purposes other than those intended by the original builder. It is not uncommon on many farms to observe buildings, originally built for a specific enterprise, being used for miscellaneous storage or other purposes of even more limited productivity.

Technological developments

The story is told of the farmer who gave as an excuse for not seeking the aid of his county extension director relative to his farm problems, "I'm not farming now half as well as I know how." This philosophy finds an important application in the farm structures field. From a technical and engineering standpoint it appears feasible to design and build a structure which would efficiently serve, based on present environmental standards, for swine fattening, beef cattle housing, loafing barn for dairy cattle, chicken house, and sheep shelter. The limited amount of work done along
this line by the Midwest Plan Service indicates the enthusiasm of farm building specialists for a multiple-purpose structure of this kind to be very limited. Acceptance by farm operators has also been disappointing. Inertia and resistance to change seem to be prominent factors in retarding the use of new and improved designs and methods of construction in the farm structures field. Despite emphasis on adequate and functional planning of farm buildings by the state agricultural extension services, the U. S. Department of Agriculture, and certain commercial concerns, considerable evidence may be found to support the hypothesis that a high percentage of farm structures are constructed without the services of an approved plan or other means of assistance representative of the best knowledge available in the field.

Further examples of the gap which exists between the development of improved practices in the farm structures field and their general field acceptance may be cited from the area of construction details. The Iowa Agricultural Experiment Station has for approximately 20 years pointed to the advantages offered by glue in the construction of farm building joints. Use of this material, although adding extremely little to the cost, contributes significantly to the strength of the joint and in turn to the general rigidity of the structure. Particular stress has been placed on the advantages of glued joints in making farm buildings more
resistant to wind damage. Timber connectors and bolt fastenings for joint construction have also been shown superior to the conventional method of nail fastening. Yet these superior methods, along with others which might be cited, have gained field acceptance at an extremely slow rate.

Responsibility for development

Activities in farm structures research, extension, and resident instruction, are generally accepted to be the responsibility of the several land grant institutions in cooperation with the U. S. Department of Agriculture. Considering the magnitude of the farmers' investment in buildings, however, effort in all the above three phases has been little more than superficial. In research activities, for example, Giese (20, p. 8), as late as 1930, reported that in the agricultural experiment stations of the United States, "...there is little research relating to farm structures now in progress...."

There appears to be a shortage of qualified workers in the field of farm structures. Since its founding in 1907, the American Society of Agricultural Engineers has recognized this field as one of the four major divisions of the profession. A review of the Membership Directory of the organization for 1950 (6) reveals that of the total membership numbering in excess of 3200, only 345 members, or 10.7 per
cent of the total, indicated farm structures as their major field of interest. Of this 345, 124 were employed by educational institutions, 165 by industry, 36 by agencies of the federal government, and the remaining 20 were engaged in private practice and unclassified pursuits. Considering the previously quoted expenditure made by farmers for new construction and repair in 1950, approximately 5.2 million dollars were expended per agricultural engineer with a major interest in the farm structures field.
CAPITAL REQUIREMENTS IN AGRICULTURE

The treatment of farm buildings as a factor in agricultural production centers about the total capital input. A general understanding of capital with reference to the agricultural firm is therefore essential as a preliminary step in the analysis of farm buildings as a production factor.

Witt (55) reported that in 1940, of the total capital used in Iowa agriculture, land represented between 55 and 60 per cent; buildings, 20 to 28 per cent; and land and buildings together from 76 to 82 per cent of the total capital in all income and tenure groups. His study indicated that buildings represented a somewhat larger and land a somewhat smaller proportion of assets on low-income farms.

The literature is well supplied with studies indicating the decreasing importance of labor as an input in agricultural production and the increasing marginal contribution of capital. Technological changes, primarily those of a labor-saving nature, have been significant in this connection. In those instances where the farm operator has been unable to secure optimum capital for one reason or another, salable products have been marketed embodying a high percentage of labor. Johnson (33, p. 643) brings this out strongly in asserting:
The substitution of labor for capital in the capital poor areas has apparently reached the point at which it takes a very large amount of labor to replace a small amount of capital. Thus, addition of more labor in the capital poor areas would increase output only slightly, while large deductions from the labor force will not markedly reduce output even if capital remains constant.

In many cases the farmer has available a family labor supply which in the formulation of expectations appears to be an input characterized by a high degree of flexibility. On the contrary, capital, and more particularly that borrowed from sources external to the firm, does not appear to have the same expansion-contraction range. This may explain in a measure, at least, the tendency which exists to use large amounts of labor and a near minimum of non-human resources, resulting in a high marginal value productivity for the latter type of factors and a low marginal value productivity for the former. This situation is cited by Heady (27), Johnson (33), Witt (55), Schultz (41), and other investigators, as one of the major problems in the misallocation of productive resources in agriculture.

Annual Capital Cost of the Farm Building Input

The farm building input represents a fixed cost to the farmer and as such does not influence marginal costs. Building expenditures most often are made in a single lump sum. Although least building outlays both in the sense of
minimum capital and minimum shelter requirements have not been determined, the capital input going into buildings as now constructed and used is invariably an addition to the fixed costs of the farm enterprise.

Such inputs may be evaluated over time based on the relation

\[ S = P(1 + i)^n \]

where,

- \( S \) = amount to which the yearly input \( P \) will accumulate over a given number of years at interest rate \( i \), dollars,
- \( P \) = annual input, dollars,
- \( i \) = interest rate, per cent,
- \( n \) = year considered in expected life span of building.

The practical use of such a treatment may be shown by assuming the farmer to be faced with the decision of constructing buildings for a 20-cow dairy enterprise. After considering various arrangements, his planning results in the necessity of a decision between the following two alternatives:

---

1It should be understood that a great number of alternative decisions might be made relative to housing accommodations. Emphasis should be placed on the methods of analysis employed and not on the two specific structures cited.
Arrangement 1

Midwest Plan No. 72303, as illustrated in Figure 5. Pole frame, loose housing, type of barn. Estimated cost $5062.50

Milking plant as built for Robert G. Stephan, Clark County, Illinois. Illustrated in Figure 5. Cost estimates kept on job $2249.03

Total $7311.53

Estimated life based on work of Wooley (56), 30 years.

Arrangement 2

Midwest Plan No. 72322, alternate Floor Plan No. 5, as illustrated in Figure 6. Conventional stanchion type dairy barn for 20 cows. Complete with milk house, Midwest Plan No. 75255-302A as illustrated in Figure 6. Estimated cost $14,000.00

Estimated life based on work of Wooley (56), 60 years.

On the assumption that both physical plants would provide acceptable market milk, and based on a uniform yearly input determined by dividing the total cost by the estimated useful life in years, Arrangement 1 would represent a yearly input of $243.70, and Arrangement 2 a like figure of $233.33.

An arbitrary interest rate of 5 per cent has been selected for use in the computations.

---

1 Estimated costs of construction of all Midwest Plans were determined by consultation with a local contractor in Ames, Iowa, familiar with the farm building field in Story County, Iowa.

2 Figures given the author in private communication by Mr. Thayer Cleaver, Agricultural Engineer, U. S. Department of Agriculture, Agricultural Research Administration, Bureau of Plant Industry, Soils, and Agricultural Engineering, stationed at the Department of Agricultural Engineering, The University of Illinois, Urbana.
Figure 5. Midwest Plan No. 72303, Pole-Type Loose Housing Barn Used in Conjunction with Milking Plant as Built for Robert G. Stephan, Clark County, Illinois
Figure 6. Midwest Plan No. 72322, Alternate Floor Plan No. 3, Two Story Gothic Roof Stanchion Barn Used in Conjunction with Milk House, Midwest Plan No. 75253-302A
Yearly inputs are shown in Table III and are plotted in Figure 7.

Applied to the swine enterprise the following arrangements might be considered:

**Arrangement 1**

Ten brood sows. Modified "A" type individual hog house, 6 by 8 feet. Midwest Plan No. 72602 as illustrated in Figure 8. Each house costing $150.00. Total . . . . . . . $1500.00

Estimated life based on work of Wooley (56), 12 years.

**Arrangement 2**

Ten brood sows. Central type of housing, 24 by 42 feet, as illustrated in Midwest Plan No. 72613, shown in Figure 9. Estimated cost . . . . 4032.00

Estimated life based on work of Wooley (56), 40 years.

On the same basis as previously described for the dairy enterprise, the yearly capital input for Arrangement 1 would be $125.00 and for Arrangement 2, $100.80. At an interest rate of 5 per cent as before, yearly inputs are indicated in Table IV and shown graphically in Figure 10.

The concept given by this analysis is considered of value as an initial step in the application of appropriate theory to a breakdown of annual capital building costs.

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1Estimated costs of construction of all Midwest Plans were determined by consultation with a local contractor in Ames, Iowa, familiar with the farm building field in Story County, Iowa.
Table III

Yearly Capital Inputs in Alternative Building Arrangements for the Dairy Enterprise

<table>
<thead>
<tr>
<th>At end of year</th>
<th>Arrange-ment 1</th>
<th>At end of year</th>
<th>Arrange-ment 2</th>
<th>At end of year</th>
<th>Arrange-ment 2</th>
</tr>
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<tr>
<td>1</td>
<td>255.89</td>
<td>1</td>
<td>244.97</td>
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Total input $17000.73 Total input first $16277.27 Total input over $86629.85
30 years life

Computations based on relation S = P(1+i)^n, where

S = amount to which the input P will accumulate over a given number of years at interest rate i,
dollars

P = annual input, dollars
i = interest rate in per cent

n = year considered in expected life span of building
LOOSE HOUSING TYPE BARN
EXPECTED LIFE 30 YRS.

CONVENTIONAL STANCHION BARN
EXPECTED LIFE 60 YRS.

ABOVE STANCHION TYPE BARN
ON ASSUMPTION OF 1 HOUR OF
LABOR SAVED PER DAY. LABOR
COMPUTED AT 0.25¢ PER HOUR.

Figure 7. Annual Capital Inputs in Alternative Building Arrangements for the Dairy Enterprise
Figure 8. Midwest Plan No. 72602, Modified "A" Type Hog House
Figure 9. Midwest Plan No. 72613, Gable Roof Hog House
Table IV

Yearly Capital Inputs in Alternative Building Arrangements for the Swine Enterprise

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<th>At end of year</th>
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Total input $2089.37 | Total input 12 years $1684.66

Total input 3-1/3 plants $6834.06 | Total input over 40 years $12785.44

Computations based on relation $S = P(1+i)^n$, where
- $S$ = amount to which the input $P$ will accumulate over a given number of years, at interest rate $i$, dollars
- $P$ = annual input, dollars
- $i$ = interest rate in per cent
- $n$ = year considered in expected life span of building
Figure 10. Annual Capital Inputs in Alternative Building Arrangements for the Swine Enterprise
Even at the relatively low interest rate selected, low in view of returns on capital invested in many sectors of agriculture, fixed inputs in anticipation of future returns are made at a substantial premium. When the anticipated return is projected over a long period of years, as in the case of long-lived types of farm structures, the size of the original yearly input, based on this analysis, becomes relatively insignificant. In the case of the dairy enterprise, Table III, the original input of $233.33, called for in Arrangement 2, approximately doubles in 14 years, triples in 23-1/2 years, and in the sixtieth year is about 18.7 times as large as the original input figure. A low annual input based on building longevity may be very misleading as to the total capital input over the expected life of the structure as compared with a relatively high annual input based on a shorter-lived structure.

Because of the near equality of the yearly inputs in the two dairy schemes, the first arrangement follows closely the schedule of the second in yearly inputs over the expected useful life of the plant. Over the 30 years of expected life of Arrangement 1, a total investment would have been made of $17,000.73, slightly more than in the case of Arrangement 2 with a total of $16,277.27.
Considering continuous building accommodations over a period of 60 years, the original capital input required in Arrangement 1 may be computed by the expression

\[ S = 7311.53 + \frac{7311.53}{(1 + .05)^{30}} = \$9003.25. \]

Reduction of the second part of the expression results in a figure of \$1691.72 which is the amount necessary to replace the barn of Arrangement 1 at the end of 30 years on the assumption that this sum is invested at zero time and earns five per cent interest, compounded annually over a 30-year period.

The same general pattern is evident in the case of the swine enterprise. In the scheme calling for the individual "A"-type houses, Arrangement 1, the original yearly input is \$24,30 greater than for the central-type housing used in Arrangement 2. Considering continuous building accommodations over a period of 40 years, the original capital input required in Arrangement 1 for 3-1/3 plants may be computed by the expression
\[ S = 1500 + \frac{1500}{(1+.05)^{12}} + \frac{1500}{(1+.05)^{24}} + \frac{1500}{(1+.05)^{36}}^{1/3} \]

\[ = 1500 + 835.26 + 257.34 + 48.07 = \$2640.67. \]

At the end of the first 12-year cycle, \$835.26 would be required to rebuild the plant had this sum been invested at zero time and allowed to earn at a rate of five percent interest, compounded annually over the first 12-year period. The other two sums may be explained in the same manner.

The above analysis suggests the advantage of the short-lived structures in meeting the challenge of obsolescence. At the close of the useful life of a short-lived building, an opportunity is available for including in the new plant improved structural features as well as new developments covering environmental conditions and control. The shorter-lived building is obviously less costly in the event obsolescence enters to prematurely shorten the useful life of the physical plant. The work of Curry (14) and Curry and Giese (15) to make permanent types of farm buildings more adaptable to changing production patterns and multiple
uses through the use of portable interior panels and certain arrangement of structural elements was essentially an effort to reduce the danger of loss through the useful life of a long-lived type of farm structure being prematurely terminated by the obsolescence factor.

Although many objections may be raised to this type of analysis, the most important is perhaps the implication of a direct relationship between the cost of a building and its expected useful life. Just what this relationship might be is not known. An example might well be cited in the case of the portable, individual, "A"-type, hog house. Accurate workmanship and the use of recommended construction practices, such as the use of glued joints, will add little if any to the first cost but will increase the life of the structure far beyond that of a shoddily built shelter costing an equal amount or more.

Too much emphasis has been placed by agricultural engineers and economists alike on illustrations citing the $2000 barn with an expected life of 10 years in contrast with the $4000 barn with an expected life of 20 years.
Field experience and observations by agricultural extension personnel tend to indicate that it may well be in a number of cases that the expected longevity may be but poorly correlated with the first cost. The importance of sound construction and basic planning incorporating such features as flexibility and functional performance can be scarcely overemphasized. These factors cannot properly be neglected in any type of analysis.

The above analysis either neglects or assumes equal labor efficiency in the two building arrangements for the respective enterprises. This point is significant in view of the opinion of many farm building specialists that farm buildings can best be justified based on their contribution to greater labor efficiency. On the assumption of a seemingly insignificant daily saving of labor in the long-lived building arrangement the entire analysis may be cast in a different light.

In Table V is shown the inputs formerly computed for Arrangement 2 of the dairy enterprise reduced by a saving of labor of one hour per day. Computations are based on an hourly rate of 25 cents. At the close of the year this saving would have accumulated to $91.25. The investment of this sum at 5 per cent at the end of each year would, over a period of 59 years, based on the principle of annuities, amount to approximately $32,264. Reduced annual inputs based
Table V

Building Capital Inputs in the Dairy Enterprise Reduced
by an Assumed Daily Decrease in Labor Requirements
Through the Use of the Stanchion Type Barn

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Totals  $86639.85  32264.56  54365.29

Computations based on relation $S = P(1+i)^n$, where

- $S$ = amount to which the input or saving, $P$, will accumulate
  over a given number of years at interest rate $i$, dollars
- $P$ = annual input or saving, dollars
- $i$ = interest rate in per cent
- $n$ = year considered in expected life span of building

Note: Assumption is made that the stanchion type barn results in 1 hour of labor saved daily in comparison with the loafing type barn. Value of labor taken as $0.25 per hour.
on this assumption are plotted in Figure 7. If labor was assessed at a rate of $1.00 per hour it is obvious that the stanchion type barn, based on the above assumptions, would show a net return based solely on increased labor efficiency.

A similar analysis applied to the two housing arrangements for the swine enterprise indicates the sensitivity of the arrangements relative to capital inputs in light of assumed increases in labor efficiency. If one hour of labor per day is assumed saved through the use of the central type of housing in comparison with the individual housing arrangement, and labor computed at 25 cents per hour, the central type of house is substantially more conservative in the capital input required over the 40-year period than the individual type. This is shown in Table VI. In Figure 10 the annual capital input of the central type house is plotted on the above assumption of savings based on increased labor efficiency. As in the case of the two dairy housing arrangements, should labor be assessed at $1.00 per hour and a daily saving of one hour assumed through the use of the central house over the individual type, the former would show a net return based on increased labor efficiency alone.

It is clear that the introduction of the labor-saving feature in the above analysis could quite conceivably point to the construction of the so-called permanent types of farm structures in preference to shorter-lived buildings. Conversely, labor-saving features in the shorter-lived
Table VI

Building Capital Inputs in the Swine Enterprise Reduced by an Assumed Daily Decrease in Labor Requirements Through the Use of Central Type Housing

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<td>582.88</td>
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<tr>
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<td>230.58</td>
<td>36.87</td>
<td>40</td>
<td>709.63</td>
<td>611.91</td>
</tr>
</tbody>
</table>

Totals $12785.44 $11023.39 $1787.05

Computations based on relation $S = P(1+i)^n$, where
- $S$ = amount to which the input or saving $P$ will accumulate over a given number of years at interest rate $i$, dollars,
- $P$ = annual input or saving, dollars,
- $i$ = interest rate in per cent,
- $n$ = year considered in expected life span of building.

Note: Assumption is made that the central type house results in 1 hour of labor saved daily in comparison with the individual type housing arrangement. Value of labor taken as $0.25 per hour.
buildings would further reduce inputs required by these types of structures and would make them increasingly attractive over the longer lived buildings.

Other features neglected or assumed constant in the above analysis are animal production and insurance costs in the case of the long-lived versus the short-lived building arrangement. Such factors would lend themselves to study by the same procedure as used above in the case of savings in labor.

Capital Rationing

In the conventional treatment of the firm by formal economic analysis, the assumption is usually made that unlimited capital is available at the going interest rate (cost). The entrepreneur utilizes capital to the point where the marginal cost of the capital is equated with its marginal return. In practice, however, even casual observation indicates that this ideal condition is seldom achieved.

Modification of this optimum condition in agriculture is brought about through rationing. With the advent of the Agricultural Adjustment Act programs came rationing in the sense of the use to which a farmer could put his land. Marketing quotas involved rationing of output. More important over time, however, has been curtailment of the amount of capital available to the farm operator, that is,
rationing of capital to the extent that because of its scarcity its marginal cost and marginal productivity were not equated. Experiences during both World War 1 and 2 support the hypothesis that in agriculture capital is substitutable for labor over a relatively wide range.

Capital rationing and expectations are intimately related. The need for capital in a given farm plan is predicated on expectations formulated by management. These expectations are efforts to evaluate the profitability of certain alternative plans from a point projected some distance into the future. Involved are such highly complex factors as price of inputs, availability of inputs, weather conditions, yields, market prices of outputs, and numerous other phenomena, all of which management must somehow combine into an intelligible plan of future action. It is obvious that more than risk is involved in the farmer's

---

1Johnson (33) believes that through a price policy based on a system of forward pricing, resource allocation in agriculture would be materially improved chiefly as a result of more accurate and meaningful expectations. His arguments are convincing.

2Schultz (42, p. 318) brings this out clearly when he states,

...if it were only risk that was at stake in the gap which separates expectations and realizations, we might presume that creditors and landlords would merely add the necessary risk premium and allow farmers to obtain all the resources they would care to hire at a price which included a payment for the risk entailed.
formulation of expectations inasmuch as the performance or occurrence parameters of many of the above factors cannot be established. It is clear the farmer is dealing with economic uncertainty.

One feature of uncertainty implied above is its profound influence on the scheduled output program of the firm. Without knowledge of prices--their direction or rate of change--management forms expectations based in some manner on the anticipated future. The range of returns to management becomes wider with increased uncertainty; that is, returns may be great or they may prove disastrously low, non-existent, or negative.

The second feature, of particular interest here, is the reaction on the part of others to the farmer's expectations. As they appear sound or unsound to the capital-supplying agencies available to the farmer, he may or may not be advanced the necessary capital to carry out his production program. This is the essence of capital rationing external to the firm. Entering the picture are several factors such as the technical understanding on the part of the credit-supplying agency of the nature of the farmer's expectations as to their soundness or defectiveness. Equally as important are the traditional restrictions on the advancement of credit

---

1This is actually the crux of management. Under perfect knowledge management would not be needed after the most profitable plan had been developed.
wherein loans are made on the basis of collateral or equity rather than on the potential productivity of the capital for which application is made. The equity position of the farmer is of major importance.¹

Witt (55) reported that within Iowa in 1940, 60 per cent of the value of the farm property was near the upper limit to which existing credit agencies would go in the advancement of capital and that 50 per cent was a more usual figure. There can be little doubt but what external capital rationing has, over time, played a very important role in the failure of farm managers to use capital to the optimum point of equating the marginal costs of such capital with its marginal value productivity.

Closely related with external capital rationing is the failure on the part of farm managers to solicit and use capital to the extent it is available to them in those cases where its use would make for more efficient allocation of productive resources. This is commonly known as self-imposed capital rationing. Several reasons might be cited for this

¹ A case in point here is the situation which existed in Decatur County, Georgia, as reported by Mr. E. F. Vickers (49), past president of the Georgia Banker's Association. In the early spring of 1949, expectations for returns from cotton were poor, whereas it appeared watermelons would be a most profitable undertaking. Capital was advanced in general, however, not on the basis of these expectations but within the traditional sphere of the net worth of the farmer. The net return on the total capital employed in watermelon production within the County was approximately 19.9 per cent as compared with a like return of only 3.4 per cent for cotton.
restrictive use of capital among farm operators such as:

1. A feeling still exists among some farmers that to borrow funds or to otherwise go into debt involves a certain social stigma irrespective of the prospective productivity of the borrowed capital.

2. The inter-relationship between the household and the firm often promotes extra caution in the borrowing of capital. Should expectations prove erroneous, foreclosure on the part of the credit-supplying agency involves most often the loss not only of the firm but the household as well.

3. Imperfect knowledge of the future resulting in inaccurate expectations may be misleading as to the true productivity of capital in the planned production schedule.

4. Restrictive use of capital may stem from past experiences wherein capital has not proven as productive as anticipated by expectations.

Witt (55) reported that in 1940 low-income farmers in Iowa were willing to borrow capital for the purchase of land but were not willing, in general, to go into debt for buildings, fences, livestock, machinery, and other productive agents aside from land. He concluded that the capital market is rationed on the supply side with reference to land and on the demand side for most other items.

Kalecki (35) in dealing with economic fluctuations in general, and with an explanation of the theory of the business
cycle in particular, presented a theory on the matter of capital commitments of the entrepreneur. He concluded that present investments must, if profit maximization is to be realized, be extended to the point of equating marginal risk with the difference between the marginal rate of profit and the rate of interest.

In summary, therefore, it would appear that capital rationing, both external to the firm and self-imposed, is a vital consideration in the allocation of resources in an optimum manner in agriculture. A graphical analysis of this point is shown in Figure 11. Cost of capital is shown on the ordinate and amount employed on the abscissa. At the going rate of interest (cost of capital) the farmer, to equate the marginal value productivity of capital with its price, would employ an amount O'X. At the point K, however, because of the equity or collateral position of the farmer further capital is not available at any price and the cost curve turns vertically upward indicating the cost of capital to be infinite. The marginal productivity of capital, AA, and the cost of capital, as indicated by the going interest rate, fails, therefore, to be equated at point X. KX may be considered to result from the influence of capital rationing external to the firm. On the assumption that the interest rate was established based on the productivity of capital rather than by tradition and various institutional influences, the cost curve might appear as
Figure 11. Concept of Capital Rationing in Agriculture
the extended broken line in the figure. At some point along the horizontal cost curve represented by the going rate of interest, the cost would increase; yet the farmer could profitably use the amount of capital indicated by the horizontal distance between K and L over and above the maximum set by the going rate of interest and by conventional practices employed by existing supplying agencies.

Self-imposed capital rationing may be shown on the same figure by imposing on the graph a second line, BB, indicating the marginal value productivity of capital as viewed by the farmer. This line could result from any one, or a combination of the factors, previously noted as causes for self-imposed capital rationing in agriculture. The farmer uses only O'N capital, whereas available to him is the amount O'K. Hence the farmer imposes upon himself the capital restriction represented by the horizontal distance NK.

Farm Building Decisions Considering Capital Resources

Decisions in light of capital productivity in agriculture

Various investigators have pointed to the high marginal value productivity of capital when used as an input in agricultural production as compared with the cost as represented by the going rate of interest. Capital rationing
has apparently resulted in a surprisingly wide discrepancy between productivity and cost factors.

Engene and Pond (17) reported, based on studies of farms in Nicollet County, Minnesota, net returns of 13 per cent on total capital invested to be usual during the period 1941-45. Johnson (33) stated that in areas relatively starved for capital, such as sections of the Piedmont in South Carolina and Georgia, a net rate of return of 19 per cent on total capital was often achieved during the year 1939. In the Corn Belt area where the influence of capital rationing is less pronounced and a surplus of labor in agricultural production is less of a problem than in most agricultural regions of the United States, Johnson (33) found in 1939 returns to capital amounted to slightly more than 10 per cent.

In light of these productivity figures, it seems pertinent to re-calculate at a higher interest rate the building costs contained in the previous section, "Annual Capital Cost of the Farm Building Input". The farmer is faced not with the going rate of interest as previously used but in reality with the true productivity of capital as employed in his farming enterprise. Hicks (31), distinguishing between the going interest rate and the rate of capital productivity, concluded that insufficient attention had been given by economists to the latter concept.

Reviewing briefly the preceding analysis in the section
cited above, the farmer building for the dairy enterprise was faced with the alternative choice of two arrangements. Arrangement 1 involved a plant costing $7,311.53 with an expected useful life of 30 years, whereas Arrangement 2 involved an investment of $14,000.00 with an expected life of 60 years. The first arrangement represented an annual capital input of $243.70 and the second an annual capital input of $233.35.

Following an identical procedure as previously used, Table VII indicates these inputs capitalized over the expected useful life span of the two arrangements with interest computed at 12 per cent, a figure which appears conservative based on capital productivity figures in agriculture as reported by the above cited and other investigators. Figure 12 illustrates the annual capital inputs comparing computations based on a going interest rate of 5 per cent and the capital productivity rate of 12 per cent, between the two housing arrangements for the dairy enterprise. The inputs for the long-lived plant become very large during the last 30 years of the expected life span.

The same observations regarding labor efficiency as previously made are equally applicable in this analysis. If, in the long-lived plant, one hour per day could be saved, in comparison with the shorter-lived buildings, the value of labor saved may be credited to the annual building inputs.
Table VII
Yearly Capital Inputs in Two Building Arrangements for the Dairy Enterprise Considering Rate of Capital Productivity in Agriculture

<table>
<thead>
<tr>
<th>At end of year</th>
<th>Arrangement 1</th>
<th>At end of year</th>
<th>Arrangement 2</th>
<th>At end of year</th>
<th>Arrangement 2</th>
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<th>Total input</th>
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<th>Total input</th>
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</table>

Computations based on relation $S = P(1+i)^n$, where

- $S$ = amount to which the input $P$ will accumulate over a given number of years at interest rate $i$, dollars
- $P$ = annual input, dollars
- $i$ = alternative interest rate, per cent (taken as 12%)
- $n$ = year considered in expected life span of building
Figure 12. A Comparison of Yearly Building Capital Inputs of Two Arrangements for Dairy Housing Computed (a) At a Going Rate of Interest of 5% and (b) At a Rate Representative of Capital Productivity in Agriculture, Taken as 12%
At a rate of 25 cents per hour one hour of labor saved per day over a year, would amount to $91.25. This sum invested at the end of each year would, over a period of 59 years, based on annuity principles, amount to $681,789.58, should the yearly sum be placed back into the farm business and earn at the capital productivity rate of 12 per cent. Should the labor saved be assessed at $1.00 per hour the building input would clearly be exceeded by the value of the labor saved and the building could be said to be rendering a net return based solely on increased labor efficiency. In case the shorter-lived plant proved labor-saving over the longer-lived arrangement, the reverse reasoning would be applicable.

It would appear that the matter of labor efficiency is of prime importance in considering the cost of the yearly capital building inputs.

Table VIII applies to the swine enterprise. The same two arrangements as used in the previous section, "Annual Capital Cost of the Farm Building Input" are employed to contrast the plant with individual, A-type houses, expected life span of 12 years, with a plant utilizing a central type house with a life expectancy of 40 years. The table shows the original annual input of $125.00 for the individual houses, Arrangement 1, capitalized at the capital productivity rate of 12 per cent in contrast with the similar input of $100.80 for the central type house, Arrangement 2,
Table VIII
Yearly Capital Inputs in Two Building Arrangements for the Swine Enterprise Considering Rate of Capital Productivity in Agriculture

<table>
<thead>
<tr>
<th>At end of year</th>
<th>Arrangement 1</th>
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- Total input
- 3-1/3 years: $11,825.24
- Total plants over 40 yrs: $86,599.85

Computation based on relation 

\[ S = P(1+i)^n \]

where

- \( S \) = amount to which the input \( P \) will accumulate over a given number of years of interest rate, \( i \), dollars
- \( P \) = annual input, dollars
- \( i \) = alternative interest rate, per cent, (taken as 12%)
- \( n \) = year considered in expected life span of building

\[ S = p(1+0.12)^n \]
Figure 13. A Comparison of Yearly Building Capital Inputs for Two Arrangements for Swine Housing Computed (a) At a Going Interest Rate of 5%, and (b) At a Rate Representative of Capital Productivity in Agriculture, Taken as 12%
'functions of two enterprises, say house and poultry.

different amounts of building capital

could be most advantageously employed to produce at the type of building arrangement which has a strong influence in the market or required to be employed at some production than. it would appear, however, that in some production as presented in the table would take on further steps.

1.5 per cent.

2.75 per cent.

3.5 per cent.

4.25 per cent.

5.0 per cent.

6.0 per cent.

7.5 per cent.

8.5 per cent.

9.25 per cent.

10.0 per cent.

10.5 per cent.

11.0 per cent.

11.5 per cent.

12.0 per cent.

12.5 per cent.

13.0 per cent.

13.5 per cent.

14.0 per cent.

14.5 per cent.

15.0 per cent.

15.5 per cent.

16.0 per cent.

16.5 per cent.

17.0 per cent.

17.5 per cent.

18.0 per cent.

18.5 per cent.

19.0 per cent.

19.5 per cent.

20.0 per cent.

20.5 per cent.

21.0 per cent.

21.5 per cent.

22.0 per cent.

22.5 per cent.

23.0 per cent.

23.5 per cent.

24.0 per cent.

24.5 per cent.

25.0 per cent.

25.5 per cent.

26.0 per cent.

26.5 per cent.

27.0 per cent.

27.5 per cent.

28.0 per cent.

28.5 per cent.

29.0 per cent.

29.5 per cent.

30.0 per cent.

30.5 per cent.

31.0 per cent.
marked differences will exist in the division of building resources between enterprises by two farmers with different amounts of available capital. Steindl (43) attacked this problem from the standpoint of overall production theory and indicated that the larger entrepreneur invariably had an objective advantage over the smaller one.

In Figure 14 is shown two such production functions. Farmer 1 has OX resources and Farmer 2 OX' as indicated by the length of the two heavy black lines below the graphs. Plotting the transformation or long-run planning curve, Figure 15, for the two operators, the first, Farmer 1 with OX resources, is faced with the upper function, AB, and Farmer 2 with OX' resources, with function CD. Curve AB is characterized by a much shorter radius of curvature than CD, indicating that as equal increments of poultry production are sacrificed it requires a lesser amount of hog production to keep on the transformation curve. The same is true, although much less emphatically, for CD where the relationship between the two enterprises is near linear.

Introduction of iso-revenue lines onto the transformation curves gives informative data. Line aa', indicating a

---

Lines aa and a'a', the first tangent to curve AB and the second to curve CD, are iso-revenue lines. They are drawn parallel to each other indicating equal price ratios. The slope of an iso-revenue line is a function of the price of the two commodities.
Figure 14. Production Functions Representing Competing Enterprises
Transformation curve drawn to twice the scale of the production functions.

Figure 15. Transformation Curves for Two Farmers with Different Building Resources
price relationship about equal for the two enterprises would suggest for Farmer 1, owning OX resources, Curve AB, the production of OX pork and OY poultry. Transferring these production quantities from Figure 15 back to the original production functions of Figure 14\(^1\) indicates 60 per cent of the total building investment should properly be expended for the hog enterprise as compared with 40 per cent for poultry.

The same iso-revenue line carried to curve CD and labeled a'a' clearly indicates that the entire building investment would be devoted to the swine enterprise. The iso-revenue line is tangent to the transformation function CD only where it touches the abscissa upon which hog production is plotted, suggesting a hog production of OD.

Altering the iso-revenue lines to positions cc and c'c', a price relationship favorable to poultry, indicates a division of the building investment between the two enterprises for both farmers. Farmer 1, with OX resources, would produce OX' of hogs and OY' of poultry, whereas Farmer 2, with OX' resources, would produce OZ hogs and OP poultry. These production quantities are marked along the appropriate axes of Figure 15. The quantities carried back to the original production functions as before\(^1\) indicate a building

\(^1\)Transfer of the output quantities from the transformation curve, Figure 15, back to the production functions of Figure 14 is not indicated in the figures. Such a procedure for the several cases cited would result in the production (footnote continued on next page)
investment for Farmer 1 divided 43 per cent for hogs and 57 per cent for poultry and for Farmer 2, 53 per cent for hogs and 47 per cent for poultry.

Again shifting the iso-revenue line counterclockwise further toward a price relationship favoring poultry production as shown by lines bb and b'b', Farmer 1 would most profitably produce 0Q hogs and 00' poultry as indicated by the point of tangency between line bb and the transformation function AB. This combination would call for 35 per cent of the total building resources to be devoted to the hog enterprise and 65 per cent to poultry production.

Line b'b' imposed on transformation curve CD indicates that under this particular price situation the entire building fund would most profitably be devoted to the construction of a poultry plant with a production of 0Q. No hogs would be produced whatsoever. This is shown by the point of tangency between the iso-revenue line b'b' and the transformation curve CD occurring on the ordinate along which poultry output is measured.

Results of the analysis with reference to the division of building resources between enterprises by the two

(cont'd) functions of Figure 14 having a needlessly confused appearance. Having determined the output quantities from the transformation curve, they may quite simply be plotted along the ordinate of the appropriate production function and the optimum percentage of building resources read along the abscissa, giving attention to the difference in scale of the two charts.
farmers as the price structure fluctuates may be summarized as shown in Table IX.

**Table IX**

**Percentages of Total Building Resources Devoted to Competing Enterprises by Two Farmers Having Different Amounts of Building Capital**

<table>
<thead>
<tr>
<th></th>
<th>Iso-revenue line</th>
<th>Hogs</th>
<th>Poultry</th>
<th>Hogs</th>
<th>Poultry</th>
<th>Hogs</th>
<th>Poultry</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>aa and a'a'</td>
<td>60</td>
<td>40</td>
<td>43</td>
<td>57</td>
<td>35</td>
<td>65</td>
</tr>
<tr>
<td>Farmer 1</td>
<td>cc and c'c'</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Farmer 2</td>
<td>bb and b'b'</td>
<td>100</td>
<td>0</td>
<td>35</td>
<td>65</td>
<td>0</td>
<td>100</td>
</tr>
</tbody>
</table>

In comparing the opportunities available to the two farmers it is clear that Farmer 2, with 0X' resources, would most likely build a plant with a view of producing all hogs or all poultry rather than a combination of the two enterprises. For price ratios lying outside the relatively narrow range between aa and bb (or between a'a' and b'b') his decision would invariably involve specialization in only one of the enterprises. Yet small price fluctuations in favor of the opposite enterprise would dictate for optimum conditions, production in the competing field from the standpoint of profit maximization. In this case had the entire building investment been devoted to the construction of a plant suitable for hog production, a change
to an all poultry enterprise would entail a substantial lowering of the poultry production function as the hog houses were used for a production for which they were not originally intended.

The concept of the short-run planning curve is useful in continuing the analysis. If, in the case of Farmer 2, a hog production plant was built to the complete exclusion of poultry, the transformation function in the short-run would slope sharply downward away from the long-run curve CD as it approached the ordinate, the axis along which poultry output is measured. To illustrate, allow the poultry production function for the all hog plant to assume the position of the dashed line in Figure 14. The short-run planning curve is then plotted and is shown as ED in Figure 15. In actual practice this is the curve along which Farmer 2 would operate once his building resources have been committed exclusively to the hog enterprise. Identical reasoning and analysis would apply to an all poultry plant as an effort was made to produce hogs in the poultry houses.

In contrast with Farmer 2, Farmer 1 with OX resources to place in buildings would, except for extreme price fluctuations, produce some combination of the two competing enterprises. As iso-revenue lines changed positions his plant would not be optimum except as the iso-revenue line arrived at the position at which his original building
decision was made, that is, a point where the short- and long-run planning curves are tangent to each other. Because the shape of the transformation or long-run planning curve is such as to indicate in all likelihood some production combination of the two enterprises over a wide range of prices (position of iso-revenue lines), the short-run planning curve would deviate less acutely from the long-run curve as compared with the situation with which Farmer 2 is faced. Although the appropriate production functions would be lowered as hogs were produced in poultry houses and vice versa, the reductions would be less penalizing inasmuch as optimum production would not depart from that on which the original building decision was made with the same degree of severity as in the case of Farmer 2 with fewer resources.

The implications of this analysis suggest that a flexible building arrangement is of more importance to the farmer with limited building capital than in the case of the farmer with greater resources. The need is shown for a building or buildings for those operators with limited capital which will perform with technical efficiency when used solely for one or another competing enterprise or for a total production involving certain percentages of both enterprises.
DIVISION OF BUILDING INVESTMENT BETWEEN
COMPETING ENTERPRISES

Economic theory should provide a clear and logical basis for determining the most profitable division between competing enterprises of the building resources which the farmer possesses. This problem is obviously of the utmost practicability. An effort is made in this section to present appropriate models illustrating how such a division may be made utilizing both long- and short-run concepts as well as decreasing and increasing returns to the building input.

Case of Decreasing Returns

Two enterprises are arbitrarily chosen, poultry and dairying. Production functions, Figure 16 for poultry and Figure 17 for dairying, indicate decreasing returns as building investment is increased, with sharply decreasing returns as the independent variable in each enterprise is extended to the upper range of output. This concept of the production function in agriculture, wherein the elasticity is less than unity throughout its entire range, was presented as a hypothesis by Kalecki (35) and is commonly held as appropriate by agricultural economists with reference to the farm building input. Building input is shown along the
Figure 17. Dairy Production Functions Decreasing Returns
abscissa and corresponding output along the ordinate. Inputs other than building investment are assumed constant.

**Long-run planning**

The farmer has available ox resources to invest in his physical plant. This might indicate any given amount of liquid capital although for purposes of illustration a figure of approximately $15,000,00 is selected. One alternative possibility would be the construction of a poultry plant using a structure as shown in Midwest Plan No. 72751, illustrated in Figure 18, which would consume the entire investment. Opposed to this plan would be the construction of a 20-cow, conventional, stanchion dairy barn shown as alternate Floor Plan No. 3, Midwest Plan No. 72322, in conjunction with the milk house illustrated in Midwest Plan No. 75253-302A. This dairy plant, shown in Figure 6, would similarly require the entire building investment.

From the production functions a transformation curve is constructed, Figure 19. AB is an iso-resource curve illustrating the production opportunities available to the farmer between the two competing enterprises, in this case poultry and dairying. The two enterprises substitute for each other at an increasing marginal rate, that is, increasingly greater quantities of poultry must be sacrificed for each increment of dairy added. The reverse also holds.
Figure 18. Midwest Plan No. 72751, Two-Story Poultry House
To arrive at an iso-revenue line, the five-year period, 1930-34, is selected and the extreme alternatives discussed above employed to arrive at ratios. The poultry plant would accommodate approximately 1500 hens. Assuming a production of 200 eggs per bird per year the output would be 25,000 dozen eggs. At the average period price in Iowa\(^1\) of 0.141 cents per dozen, this would represent an income of $3,525.00. Assuming half of the flock to be marketed yearly at an average weight of 4 pounds, the total marketable meat would amount to 3,000 pounds, which at the average period price of 0.117 cents per pound would represent an additional income of $351.00, or a total gross income figure of $3,876.00.

In a similar manner figures are obtained for the dairy plant. Twenty cows would be accommodated. Assuming an annual production of butterfat of 250 pounds per animal and employing the average period price\(^1\) of 0.25 cents per pound results in an income of $1,250.00. To this is arbitrarily added an animal value of 30 per cent of the butterfat return for a total, annual, gross income of $1,625.00.

Assuming net return on the gross incomes of the competing enterprises to be equal, an iso-revenue line may be established by the ratio of the respective gross incomes, that is, 3,876 over 1,625 or approximately 2.4:1. This line

is marked 1-1 in Figure 19. The point of tangency, A', between the iso-revenue line and the transformation function gives the optimum output for each of the competing enterprises based on the five-year period 1930-34. Projecting this optimum point to the respective axes gives an optimum poultry output of 90.5 per cent and for dairying 62 per cent. These output percentages carried to the original production functions indicates the most profitable division of the building investment to be 63 per cent for poultry and 37 per cent for dairying. For clarity these percentages are appropriately marked on Figures 16, 17 and 19. The analysis, in summary, suggests 62 per cent of the dairy output with 37 per cent of the building investment as compared with 90.5 per cent of the poultry output with 63 per cent of the total building investment.

Under these circumstances it is clear that certain adjustments would be necessary in the design of the buildings to be constructed based on cost aspects. The relatively high-cost buildings as originally planned would not be satisfactory. In the building field it is recognized that the cost of building accommodations do not vary in direct proportion to the number of animals housed; that is, a dairy plant for 20 cows will cost considerably more than one-half of a comparable plant constructed for 40 cows. This is particularly true in the case of the conventional, stanchion

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1This ratio computed for the year 1950 on the above basis and with prices taken from the same source was approximately 1.9:1.
type dairy barn, or any high grade permanent type of building, but holds also, although less emphatically, in the case of the loose housing barn. Certain economies in material and labor as well as such items as refrigeration requirements, plumbing lay-outs, milking stalls and storage accommodations may be achieved, wherein the cost of housing additional animal units becomes less as the size of the herd increases within certain limits.

In the case at hand, a modification of Midwest Plan No. 72302, shown in Figure 20, adjusted for 12 cows (20 multiplied by 62 per cent) would be worthy of consideration. With an allowable investment of $5,560.00 ($15,000.00 multiplied by 37 per cent), the strictest economy would be required for the construction of the building including, in all likelihood, substitution of a trench silo for the upright type shown, reduction of milk room to the barest essentials, substitution of a graveled or cindered lot for the paved lot shown, and other economies as might be exercised within the limitations of the effective milk code.

Likewise alterations in the proposed poultry plant would be necessary. In general, building adjustments in this enterprise would be more simple than in the case of the dairy plant because of the absence of code specifications, lighter construction, and the nature of the producing units to be housed. Three units as illustrated in Midwest Plan No. 72714, Figure 21, might well be considered in lieu of
Figure 20. Midwest Plan No. 72302, Pole-Type Loose Housing Barn
Figure 21. Midwest Plan No. 72714, Straw Loft Poultry House
the original plan, Midwest No. 72751, Figure 18. The former would offer a lower, lighter structure more adaptable to construction by the farm operator and his labor supply who, in general, are inexperienced in detailed construction procedures. Substitution of a shed roof for the gable type shown might be considered as a cost-reducing measure.

One logical selection might be, therefore, three poultry units patterned after Midwest Plan No. 72714, Figure 21, and one dairy unit patterned in accordance with Midwest Plan No. 72302, Figure 20. This arrangement would have an added advantage of flexibility which is of particular importance in the short-run operational plan. This will be discussed in a following section. Should the iso-revenue line take the position of 2-2, Figure 19, the optimum dairy output would increase to 91 per cent and poultry output would decrease to 58 per cent. The optimum point of production would be at point B'. The loose housing arrangement would permit expansion of the dairy herd to 18 cows with fairly adequate housing facilities. If need be one of the poultry structures could be used for a storage area for feed and/or bedding and a larger bedding area thus provided in the loose housing barn. Conversely, should the optimum production be at point C' as indicated by iso-revenue line 3-3, Figure 19, the plant would be within reasonable limits of adaptation for the increased poultry production and the lesser emphasis on dairying.
Short-run planning

The analysis becomes more meaningful from this point if short-run planning curves are employed. Haday (30) uses such curves effectively in dealing with uncertainty in market relationships and resource allocation. Once resources are committed to a specific operational plan, the transformation or long-run curve becomes of historical significance only and actual planning centers about the short-run curve. Appropriate short-run curves exist for each point on the long-run curve upon which building decisions might be based. The relationship can best be visualized by considering the long-run curve as an envelope containing an infinite number of short-run curves. It is not possible for the short-run curve to lie outside the long-run or envelope curve. The two curves are tangent to each other at the point upon which the original building decisions are made. This fact is significant because production is realized as viewed originally on the long-run curve only in that case where the iso-revenue line assumes the identical position as at the time the original plan was made, for at this point only is the long- and short-run curves tangent to each other at the location on the long-run curve touched by the iso-revenue line.

To illustrate the concept of short-run curves, the two production functions shown in Figures 16 and 17 for the
poultry and dairy enterprises, respectively, are reproduced in Figures 22 and 23. Lines OA'C in these Figures indicate the new production functions after commitment of resources to the construction of a physical plant based on the iso-revenue line 1-1, Point A', Figure 19. Point A', in Figures 19, 22, 23 and 24, represents the same level of production between the two competing enterprises.

At Point A' in Figures 22 and 23 the two production functions coincide, but other than at this point the dashed curves representing production after construction of the plant, lie below the original functions which faced the farmer. This is explained based on the decreased efficiency stemming from raising poultry in dairy barns and producing butterfat in poultry houses, as the operational plan would necessarily entail as it moved away in either direction from the original plan of production. The two curves for poultry production, Figure 22, deviate less sharply from each other than the dairy production curves shown in Figure 23, in view of the large proportion of resources devoted to poultry production in the original plan and also based on the hypothesis that the loose-housing dairy barn would be more efficient in producing poultry than in the case of poultry houses used for the production of butterfat.

The short-run planning curve for the operational plan previously suggested, Point A', and based on the lowered
Figure 22. Poultry Production Function After Commitment of Building Resources
Figure 29. Daily Production Function After Commitment of Building Resources
production functions of Figures 22 and 23, is shown by EA'\(B\) in Figure 24. In the event the iso-revenue line would change to the position 2-2, Figures 19 and 24, a position heavily favoring dairying, the plant would not involve a production of 91 per cent of the dairy output and 58 per cent of the poultry production as shown in the long-run curve, Figure 19, but instead only 80 per cent dairying and 66 per cent poultry as indicated in Figure 24.

It is clear that should the iso-revenue line shift to position 3-3, Figure 19, the penalty would not be severe based on the curve along which the farmer operates once his building resources are committed, that is, the short-run curve. Curves EA'\(B\) and DA'\(F\), Figure 24, do not deviate appreciably as poultry production is increased to the left of Point A'.

A more extreme case is shown by assuming the farmer to build a stanchion type dairy barn for his 12-cow herd. Inflexibility in this arrangement would be particularly costly as operations centered about increased dairy production and a corresponding decrease in poultry. The dairy production function might be assumed to lower as shown by line OA'D, Figure 23, and the derived short-run curve would take the position EA'C, Figure 24, assuming no change in the efficiency of the plant in poultry production beyond that previously shown. The iso-revenue line 2-2, in this case,
Figure 66: Poultry output diverted from assumed production.

Dairy output

80%

66%

Poultry output
would result in no further butterfat production despite the
heavily favored price position of the dairy enterprise over
the position indicated by line 1-1, Point A', Figure 19.
This is shown by the fact that the iso-revenue line 2-2,
Figure 24, is tangent to the short-run curve EA'C only at
Point A', the point upon which the original building deci-
sion was made. From a practical standpoint this simply im-
plies that as the price ratio changes heavily in favor of
dairying the farmer would not be in a position to take ad-
vantage of the situation through increased emphasis on the
production of butterfat.

An identical analysis could be made for any point which
might be selected on the original long-run or transformation
curve as dictated by a given iso-revenue line. Although
other factors are of importance in analyzing deviations be-
tween the long and short-run planning curves, building ar-
rangements involving specialization is one of the major
factors in this connection, particularly in operating schemes
involving competing livestock enterprises.

Case of Increasing Returns

The analysis is extended to consider the case of in-
creasing returns. As previously pointed out, the shape of
the building production function in agriculture has never
been determined, that is, the relation between output and building investment is not known. For any enterprise requiring building facilities the concept of increasing returns to building investment at the lower levels of production is entirely realistic. Also conceivable, however, are increasing returns at the higher levels of output particularly in enterprises characterized by highly specialized requirements such as close control of environmental conditions. Examples might include purebred cattle raised for show and breeding purposes; eggs produced under rigid specifications for use by a hatchery; and the production of certified fluid milk. Technological developments in the farm building field, such as ventilation of animal shelters, might also introduce conditions under which increasing returns would be realized.

The analysis is continued along the same lines as before. The farmer has OX building resources which he proposes to divide between the poultry and dairy enterprises based on profit maximization principles. He is faced with the production function OAB for poultry, Figure 25, and function OAB for dairying, Figure 26. It will be noted that both production functions yield substantial increasing returns of output particularly in the upper range of the building investment.

The transformation or long-run planning curve is
Figure 25. Dairy Production Functions, Increasing Returns
derived from the production functions and is shown as line OAB, Figure 27. It is convex to the origin indicating that as equal increments of poultry production are sacrificed it requires an increasing amount of dairy production to keep on the same curve. By introducing the iso-revenue line 1-1, as previously used in Figures 19 and 24, the slope of which is a function of the ratios of the average prices for the two commodities, poultry and dairy, for the period 1930-34, Point A, Figure 27, is determined as the optimum point of production. This point suggests 56 per cent of the total dairy production with approximately 65 per cent of the total building investment being devoted to dairying, and 26 per cent of the total possible poultry production with a plant requiring the remaining 35 per cent of the building resources.

The optimum Point A from Figure 27 is located on the respective production functions, Figures 25 and 26. As the plant is constructed and resources thus committed based on this point of production, the production functions will change shape. Assumed changes are indicated in the above figures by lines OAC in both instances. From these lowered production functions, the short-run planning curve is derived as shown by line O'AB' in Figure 27.

The short-run curve is of such a shape as to make iso-revenue line 1-1 appear as a lever resting on a fulcrum at
Figure 37. Long and Short-Run Planning Curves for the Poultry and Dairy Enterprises Derived from Assumed Production Functions Exhibiting Increasing Returns

Note: Scale of production functions has been doubled in the derivation of this figure.
Point A, Figure 27. It is clear that Point A will, in all cases, approximate the optimum division of building resources between enterprises, that is, the system has a high degree of stability. For two commodities, therefore, exhibiting increasing returns to building investment over a significant range of output, the division of such building resources between the two enterprises is determinate, and such a division once properly computed will not change appreciably with varying price ratios between the two commodities.
BUILDING DECISIONS IN LIGHT OF FLEXIBILITY

Flexibility as Related to Price Relationships

The concept of flexibility may advantageously be examined through a study of short-run planning curves. In general, as greater flexibility is built into the physical plant the less the departure or deviation of the short-run curve from the long-run or transformation curve facing the farmer prior to the commitment of building resources.

In Figure 28 is shown two short-run planning curves. Each curve represents an equal outlay of resources or costs. Curve AB because of its greater degree of curvature (shorter radius) may be considered as representing a plant with a higher degree of inflexibility than Curve CD. The latter curve is drawn to show a more flexible building arrangement between the two competing enterprises, poultry and hogs.

Between points x and y, Figure 28, it is clear that for any production combination the inflexible plant, Curve AB, would invariably give the greatest return, that is, for a given production of one commodity more of the other would be produced. Should the iso-revenue line take the position aa or bb the farmer would conceivably be indifferent as to
Figure 28. Production Planning Using Short-Run Curves
which type of plant he might construct since optimum production points could be achieved on either Curve AB or Curve CD. Lines aa and bb are tangent simultaneously to the two short-run curves. The same indifference might be shown if the farmer anticipated the price relationships to vary precisely from the position of line aa to the position of line bb. Definite preferences between the two plants would be shown in the circumstance where the effective iso-revenue line had a slope less than bb but greater than aa wherein the inflexible plant, Curve AB, would logically be selected. Should the iso-revenue line take a position with a slope greater than bb, such as b'b', or less than aa, such as a'a', the selection would center about the more flexible plant, Curve CD.

Flexibility is thus closely associated with price relationships. The significance of price fluctuations is well established and requires little elaboration at this point. In Iowa during 1933, hogs were selling for 0.034 cents per pound and eggs for 0.11 cents per dozen, a ratio of 1:3.24. In 1950, the ratio had narrowed to 1:1.65. As the farmer formulates his expectations he may decide upon a physical plant involving a relatively high degree of flexibility even though price relationships over the range of his past knowledge would seemingly indicate the logical selection of an inflexible plant. Aspects of uncertainty may enter heavily
into his expectations and the lesser productivity of the flexible plant over time as viewed in light of the farmer's expectations may be considered worthwhile as a hedge against price relationships which possibly might prove more erratic in the future than in the past.

Hart (24, pp. 25-26) presented a clear concept of flexibility. He stated:

...the need of flexibility arises chiefly from a combination of uncertainty and capital-market imperfections.... Flexibility in plant and organization means a structure which is not optimal for any horizontal production schedule at any level whatsoever but offers better prospects of net receipts for a prospective varying rate of output than would any structure adapted to constant output.

Derivation of Short-Run Planning Curves
Based on Space Requirements

Case 1. Farmer with moderate building resources

Based on farm building plans currently available to the farmer, the analysis is continued to consider a few specific possibilities which might be considered by him in the establishment of housing facilities for competing livestock enterprises. Any point of the long-run or transformation curve might be selected as dictated by the position of the iso-revenue line at present, at some time in the past, or in accordance with an anticipated position in the future.

Application of long-run versus short-run planning may
be accomplished through the consideration of livestock space requirements alone. This procedure neglects or considers constant such factors as amount of labor required, efficiency of labor, feed requirements, efficiency of feed utilization, disease control measures, and other like factors, closely associated with the most advantageous farm building design and lay-out. Empirical measurement of the above factors, in addition to others not mentioned, would be necessary to achieve an accurate picture of short-run, long-run planning relationships.

It is assumed that the farmer has $14,500.00 to invest in housing involving a production program between competing hog and poultry enterprises. Consulting the Midwest Plan Service Catalogue (49), the farmer selects for his hog enterprise a building similar to Midwest Plan No. 72613 with a view of adjusting the building in length to meet the space requirements imposed by the scheme of operation which he may subsequently develop. A perspective and floor plan of the structure has been previously shown in Figure 9. The estimated cost of a building of this general type, incorporating materials and facilities to provide optimum environmental conditions for hogs on the basis of the best

1As previously explained, estimated building costs in this study were obtained from a building contractor in Ames, Iowa, familiar with and experienced in the construction of farm buildings within Story County, Iowa.
technical knowledge currently available, is $4.00 per square foot.

For the poultry plant the farmer selects Midwest Plan No. 72725, shown in Figure 29. His intentions are to build a suitable number of units to provide space for the size of flock he later decides to accommodate. At an estimated cost of $5.75 per square foot, the plant can be constructed to provide proper environmental conditions for housing the flock based on the latest recommended technical specifications.

For purposes of the analysis 50 laying hens will be considered as one poultry production unit and one brood sow as one hog production unit.

The long-run or transformation curve may now be developed based on assumptions involving combinations of production possibilities. The first point may be determined by assuming an all-poultry plant. Each house contains 400 square feet, accommodates four poultry production units, and would cost an estimated $2,300.00; permitting through the expenditure of the total building investment the construction of 6.3 poultry houses. In a similar manner each hog house, accommodating ten hog production units, would contain 1008 square feet and would cost an estimated $4,032.00. The total expenditure toward an all-hog program would permit the construction of 3.6 hog houses. Table X indicates
Table X
Long-Run Production Opportunities Available to a Farmer Between Competing Livestock Enterprises Considering a Specific Investment in Housing Facilities

<table>
<thead>
<tr>
<th>Hog houses</th>
<th>Hog production units</th>
<th>Poultry houses</th>
<th>Poultry production units</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>Value</td>
<td>$</td>
<td>No.</td>
</tr>
<tr>
<td>3.6</td>
<td>14,500</td>
<td>36</td>
<td>0</td>
</tr>
<tr>
<td>3.0</td>
<td>12,096</td>
<td>30</td>
<td>1.05</td>
</tr>
<tr>
<td>2.0</td>
<td>8,064</td>
<td>20</td>
<td>2.8</td>
</tr>
<tr>
<td>1.0</td>
<td>4,032</td>
<td>10</td>
<td>4.55</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>6.3</td>
</tr>
</tbody>
</table>

Several combinations which might be computed and used by the farmer in his long-run planning.

Plotting the hog production units versus the poultry production units results in the linear, long-run planning curve EA, Figure 30. The poultry enterprise requires an investment of $575.00 per production unit whereas the hog enterprise requires an investment of $403.20. These figures are reflected in the slope of the long-run curve.

It is assumed that the farmer elects to produce a combination between the two enterprises as indicated by Point K, Figure 30, calling for six units of hogs and 21 units of poultry. The hog house would be 24 by 28 feet and would
Figure 29. Midwest Plan No. 72725, Two Story Poultry House
Figure 30. Short and Long-Run Planning Curves for the Farmer with Moderate Building Resources
cost an estimated $2,688.00. Four poultry houses, as shown in Figure 29, might be constructed to accommodate four poultry production units each. The fifth house might be 20 by 25 feet in size which would provide ample space for the five remaining poultry production units. At estimated costs previously given, the construction scheme would involve an expenditure of $14,763.00 which is sufficiently close to the original investment figure of $14,500.00 for purposes of the analysis.

With his building resources thus committed, price relationships change heavily in favor of poultry. The farmer may elect to go to an all-poultry production schedule. The hog house contains 532 square feet of usable floor area, after deducting the feed room area of 140 square feet, and considering the alleyway usable space for poultry production. Allowing four square feet of floor area per bird, the hog house would provide space for 2.66 poultry production units for a total overall production of 23.66 poultry units. This is a point on the short-run planning curve; with no hog production, 23.66 units of poultry could be produced.

Assuming the reverse situation to occur, the farmer conceivably might attempt hog production in the poultry houses. In poultry houses of the type cited, the capacity of the structure for hog production would not be in proportion to the capacity based on the floor area available
for poultry, but would be considerably lower. Increased emphasis on hog production to the extent of nine units might be realized by using the 20 by 25 foot poultry house for the additional three sows. Poultry production would then be 16 units as provided by the remaining four poultry houses. Should an all-hog program be attempted, the 20 by 20 foot poultry houses might house two sows each, which along with the three sows from the 20 by 25 foot poultry house, and six from the original hog house, would make a total of 17 hog production units. In a similar manner other points may be computed to arrive at short-run planning curve XKZ, Figure 30, as indicated in Table XI.

Table XI
Short-Run Production Possibilities After Commitment of Building Resources Between Hogs and Poultry with Emphasis on the Latter Enterprise

<table>
<thead>
<tr>
<th>Production units</th>
<th>Hogs</th>
<th>Poultry</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
<td>23.7</td>
</tr>
<tr>
<td>2</td>
<td></td>
<td>23.0</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td>21.0</td>
</tr>
<tr>
<td>9</td>
<td></td>
<td>16.0</td>
</tr>
<tr>
<td>12</td>
<td></td>
<td>9.0</td>
</tr>
<tr>
<td>17</td>
<td></td>
<td>0.0</td>
</tr>
</tbody>
</table>
Considering the original production scheme, Point K, emphasis was placed on poultry. The pronounced deviation of the portion of the short-run curve, KZ, from the corresponding portion of the long-run curve, KLA, has important implications. The high degree of inflexibility of the type of poultry house selected in a shift from poultry to hogs is clearly shown. From Point K to Point Z an increase of 11 hog production units is indicated. This increase is achieved by devoting all of the poultry housing facilities constructed, based on decision point K, to hog production. A building outlay of approximately $12,000.00 is thus used in producing the 11 additional hog production units at an average building capital outlay of $1,090.00 per sow. This figure should be compared with a similar outlay of only $450.00 per hog production unit housed in the original hog house constructed at the decision point K. A shift from poultry to hog production in facilities originally intended for the former, and of the type of poultry housing used in the above analysis, is accomplished only at a great increase in the building capital outlay per hog production unit housed. This results from the high degree of inflexibility of the small poultry unit as an effort is made to use it for the competing hog enterprise.

The analysis is continued to consider a second point on the long-run curve, Point L, Figure 30. The farmer's
original building decision here would involve the production
of 24 hog production units and 8-1/2 poultry production
units. Three hog houses, 24 by 35 feet, are constructed
based on the plan previously cited and shown in Figure 9.
Two poultry houses, 20 by 21 feet, pictured in Figure 29,
are provided for the poultry. At estimated costs previously
quoted, the construction program would come closely to the
limit set of $14,500.00, exceeding it by a sum of $410.00.

Should additional emphasis be placed on hog production,
two brood sows might be placed in one of the poultry houses.
A production of 26 units of hogs and 4.25 units of poultry
could be achieved under this arrangement. Should the plant
be devoted to an all-hog production program 28 hog produc-
tion units could be realized. In a similar manner points
to the left of decision point L, Figure 30, may be com-
puted as additional emphasis is placed on poultry. Each
of the three hog houses contains a usable area of 700 square
feet which would accommodate 175 hens, or 3-1/2 poultry
production units, allowing four square feet per bird. By
assuming other production possibilities, additional points
on the short-run curve may be readily determined, as shown
in Table XII.

Evident from the short-run curve so derived is the
adaptability of the hog houses to a shift toward increased
poultry production. From the original decision point L,
Table XII

Short-Run Production Possibilities After Commitment of Building Resources Between Hogs and Poultry with Emphasis on the Former Enterprise

<table>
<thead>
<tr>
<th>Production units</th>
<th>Hogs</th>
<th>Poultry</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>19.0</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>15.5</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>12.0</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>8.5</td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>4.25</td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>0.0</td>
<td></td>
</tr>
</tbody>
</table>

wherein production emphasis is largely on hogs and hence the greatest portion of the total building capital so placed, the portion of the short-run curve LW slopes gradually away from the corresponding portion of the long-run curve LKE, Figure 30. From this same production point a shift to further hog production by using part or all of the poultry houses results in a very sharp deviation of the portion of the short-run curve LQ from its appropriate counterpart, the portion of the long-run curve LA.

Long-run curve EKLA, Figure 30, may be considered an envelope of an infinite number of short-run planning curves. Should the appropriate iso-revenue line by its point of tangency with the long-run curve suggest an all-hog
production plant, the farmer's original building decision might well center about Point A, Figure 30. With a linear long-run planning curve the farmer would invariably specialize wholly in one or the other of the competing enterprises if he was certain of future price relationships between enterprises and did not anticipate significant fluctuations.

Assuming the original production point to be at A, Figure 30, the short-run curve would be a straight line gradually sloping away from the long-run curve throughout its length. The implications of the linear short-run planning curve might well be a shift from one enterprise in a given production period to a completely new enterprise in the succeeding production period. Other factors in addition to buildings would be of importance here, however, such as specialized equipment, feeders, waterers, and like items, which would be far from perfectly flexible, even though the building might in practice prove very efficient in alternative enterprises. Labor more skilled in one enterprise than another and the personal preference of the operator as to the nature of the enterprise to be conducted would be other factors which would seemingly tend to retard pronounced accentuation of commodity cycles resulting from increased flexibility of farm buildings as suggested by Heady (30).
Case 2. Farmer with limited building resources

The same type of analysis is applicable to a farmer with limited building capital. Of particular significance in this connection is the young operator with limited funds attempting to get a start in farming. Also the tenant farmer, when for one reason or another he is not supplied the buildings which he desires by the landlord, may elect to provide his own shelter. Under such conditions his primary interests other than utility may be transportability and a minimum capital outlay.

Assuming available building funds of approximately $4,200.00, the farmer wishes to investigate production possibilities between poultry and hogs as major competing enterprises. Again referring to the Midwest Plan Service Catalogue (38), he decides on Midwest Plan No. 72602 for his hog production. This portable "A" type hog house, accommodating one hog production unit, has been previously shown in Figure 8. Estimated cost of constructing the unit is $150.00.

For the poultry enterprise he decides on Midwest Plan No. 72723, shown in Figure 31, a house 20 by 20 feet, capable of accommodating two poultry production units. Cost of construction has been estimated as $2.65 per square foot. Insulation and ventilation features were omitted to reduce cost and make the structure more comparable in construction
Figure 31. Midwest Plan No. 72723, Shed Roof Poultry House
with the type of hog house used. Each house would cost $1,060.00.

Should the farmer elect to produce all hogs, it would be possible for him to build 28 houses and produce 28 hog production units. An all-poultry scheme would permit the construction of four poultry houses for a total production of eight poultry units. The production of 14 hog units would permit construction of two poultry houses for a poultry production of four units. Other production possibilities may be computed to determine points on the long-run planning curve ABC, Figure 32.

Assume that the farmer elects to build for a production as indicated by Point B, Figure 32. Production would be divided between 14 hog production units and four poultry production units. Should added emphasis be placed on hog production each poultry house might house two sows. Thus should 16 hog production units be produced, two production units of poultry could be realized. An all-hog, no-poultry scheme, would entail the production of 18 hog production units.

Should additional emphasis be placed on poultry production and less on hogs, each hog house would, based on space requirements alone, accommodate approximately one-fifth of a poultry production unit. The production of ten hog units would permit 4.8 poultry production units. The
Figure 32. Short and Long-Run Planning Curves for Farmer with Small Amount of Building Capital
short-run planning curve DBE, Figure 32, is derived from the several production opportunities available to the farmer after the commitment of his building resources to a specific building scheme as dictated by the selected production, Point B, on the long-run planning curve.

Essentially the same comments as made in Case 1, with reference to the inflexibility of the small poultry house when an effort is made to convert it for use in competing livestock enterprises, are applicable in Case 2. The sharp deviation of the short-run curve from its long-run counterpart to the right of Point B, indicates how poorly small poultry house units are adapted to hog production. Conversely the hog house is more inclined toward flexibility as shown by the very gradual departure of the portion of the short-run curve BE from the long-run curve as increased emphasis is placed on poultry production.

Practical Aspects of Farm Building Flexibility

From a practical standpoint the use of hog houses for poultry production appears more realistic than the reverse situation. Small poultry units, such as the 20 by 20 foot structure used in the preceding analysis, fail to be readily adaptable to hogs, dairy cows, or sheep. Even though conversion of small poultry units to other animal enterprises was under certain conditions considered feasible, the
housing cost per animal accommodated in the alternative use would likely be high. This possibly accounts for the often observed low alternate use value of the small poultry unit particularly when used in multiples in a commercial size poultry enterprise. Irrespective of price relationships the commercial poultry raiser will seldomly convert to competing enterprises with a view of using his existing plant for alternative purposes. Lanham and Gannon (37) advanced the hypothesis that the commercial poultry raiser meets the challenge of economic uncertainty chiefly through the formation of a specific and definite course of action and from this point making every effort toward carrying the plan through to completion come what may.

The inflexibility of the small poultry housing unit has not gone unobserved in other quarters. A member of the Poultry Housing Sub-Committee of the North Central Region Farm Structures Coordinating Committee has stated informally to the author that some, if not the majority, of the members of the group favored the small poultry housing unit only in those cases where the enterprise was clearly a small, supplementary undertaking. In the case of poultry as a major farm enterprise, thought centered about a structure 24 or 36 feet in width and of such a length and general design as to permit cleaning by mechanical means. It is clear that such a structure would have a much higher alternate use
value than small units used in numbers sufficient to accommodate the commercial size flock.

This discussion is not without significance for Iowa agriculture. Stewart (44) estimates about 95 per cent of all Iowa farms have some poultry. According to this writer flocks ranging in size from 50 to not more than 200 birds are by far the most common and in the few instances where large flocks of over 400 hens are found they are most frequently in combination with dairying. Stewart suggests a supplementary relationship between hogs and poultry particularly in the case of the young farmer with growing children. In this instance poultry possibly utilizes labor which otherwise would go unused. The production relationship between hogs and poultry on Iowa farms where hog production is the major enterprise may well be as shown in Figure 33. Curve APB represents the production opportunities available to the farmer between the two enterprises, poultry and hogs. An output ofOX poultry may be realized with no sacrifice in hog production. The hypothesis may be projected that the production point P, as determined by the point of tangency between the planning curve APB and the isorevenue line ab, is one of considerable stability. In this case little possibility exists that an effort would be made to shift poultry housing facilities to hog production or vice versa.
on Iowa Farm Crop Production Hogs as a Main Intensive

Figure 22. Opportunity Curve for Poultry-Hog Production

OUTPUT OF POULTRY

OUTPUT OF HOGS

A

B

X

O
The desirability of increased flexibility in farm buildings has been pointed out by agricultural engineers and agricultural economists. Three investigators, Curry (14), Curry and Giese (15), and Heady (29), have previously been cited. Stemming largely from the basic work of Curry (14), Midwest Plan No. 73136 was issued in 1936. Originally consisting of two sheets, the plan presented a general purpose barn, designed on a modular dimension basis with a three-foot multiple in width and a four-foot multiple in length. Three 3-by-12-inch continuous lintels, spanning from plate to plate at the ends of the building, relieved the end-wall framing from load bearing requirements. Flexibility in end-wall design was thus achieved, not only from the standpoint of door and window placement, but also for increased length requirements if needed at some later time. Two rows of four inch outside diameter, steel pipe columns were placed eight feet from center to center lengthwise of the structure, centered two feet, two inches, on either side of a center line running lengthwise through the building. The design resulted in an alleyway lengthwise of the building of a clear four foot dimension in width. For a 36-foot building width, clear areas on either side of the alleyway, 15 feet in width throughout the length of the structure, were provided. In the original design hay storage was provided overhead. The roof was of Gothic design, using laminated, glued, bent rafters.
Further progress has been made by the Midwest Plan Service on this basic design. Now in the process of review are two additional sheets. Details of wood panels are being developed in an effort to adapt the structure to a variety of uses. In the construction of pens, wooden uprights are bolted to the joist above and fastened to the floor by means of a pipe insert connection. Steel plank channels, commercially available through barn equipment manufacturers, are used to hold the horizontal pen members in place. Consideration is also being given to a self-supporting, gable-type roof providing no hay storage above and eliminating the need for interior columns.

The tentative plan is shown in the Appendix. The composite floor plan, Sheet 4, illustrates the use of the structure in housing horses, beef cattle, hogs, poultry, milk cows, and a bull.

Traditional practices and customs inherent in the farm building field resist developments as represented by a plan of this nature. Work of this kind, however, may well prove to be a point of departure from which increased flexibility in farm buildings may be ultimately achieved.
CONCLUSIONS

1. An analysis of farm structures as a production factor in agriculture will invariably involve both economic and engineering considerations. (p. 11 and p. 23)

2. Farm building expenditures cannot in all cases be explained based on production principles. Consumption aspects are often of importance. (pp. 23-24)

3. Until it is possible to estimate with some accuracy the shape and general nature of the building production function, speculation will continue to surround the contributions made by farm buildings as an input factor. (p. 25)

4. An economic analysis of the role of farm buildings in agricultural production would be greatly facilitated by more precise specifications on the part of technologists as to optimum environmental conditions which the building should provide. (p. 26)

5. Fixed costs in the farm operation must be viewed from the standpoint of the level of production before being adjudged good or bad. (pp. 27-29)

6. Inertia and resistance to change appear to be important factors in retarding the use of new and improved designs and methods of construction in the farm structures field. (p. 32)
7. Considering the investment involved and the total annual expenditures for farm buildings, there appears to be a shortage of qualified workers in the field. (pp. 33-34)

8. The shorter-lived building is likely to be less costly than the long-lived building in the event obsolescence enters to prematurely shorten the useful life of the physical plant. (pp. 49-50)

9. A low annual capital input based on building longevity may be very misleading as to the total capital input over the expected life of the structure as compared with a relatively high annual capital input based on a shorter-lived structure. Even at a relatively low interest rate fixed inputs in anticipation of future returns are made at a substantial premium. (p. 48)

10. There is some evidence to support the hypothesis that the expected longevity of a farm building is but poorly correlated with its first cost. (pp. 50-51)

11. A relatively small daily saving in labor takes on major significance in the making of logical recommendations to farmers as to the type of buildings and their arrangement most advantageously employed in a given situation. (p. 51)

12. Capital rationing, both external to the firm and self-imposed, is a vital consideration in the allocation of resources in an optimum manner in agricultural production. (p. 60)
13. Building capital inputs should be capitalized not at the going rate of interest but rather at a rate representative of the capital productivity prevailing within the farm operation. This in no manner minimizes any labor-saving features provided by the building particularly if the value of the labor saved is placed in the business and allowed to earn at the capital productivity rate. (p. 63)

14. Recommendations to farmers as to optimum building arrangements between enterprises should be strongly conditioned by available capital resources. (p. 69b)

15. A flexible building arrangement is of more importance to the farmer with limited building capital than to the farmer with greater resources. (p. 77)

16. Once resources are committed to a specific operational plan, the long-run planning curve becomes of historical significance only and actual planning centers about the short-run curve. (p. 90)

17. In analyzing deviations between the long- and short-run planning curves, building arrangements involving a high degree of specialization are of major importance, particularly in operating schemes involving competing livestock enterprises. (p. 96)

18. For two enterprises exhibiting increasing returns to building investment over a significant range of output, the division of such building resources between the two enterprises is determinate, and such a division once
properly computed will not likely change appreciably with varying price ratios between the two enterprises. (p. 102)

19. The concept of farm building flexibility may advantageously be examined through a study of short-run planning curves. In general, as greater flexibility is built into the physical plant the less the departure of the short-run from the long-run planning curve. (p. 103)

20. Aspects of uncertainty may enter heavily into the farmer's expectations and the lesser productivity of the flexible plant over time as viewed in light of his expectations may be considered worthwhile as a hedge against price relationships which possibly might prove more erratic in the future than in the past. (p. 106)

21. The small poultry housing unit exhibits a high degree of inflexibility as an effort is made to use it for competing livestock enterprises. (p. 123)

22. Specialized equipment, labor more skilled in one enterprise than another, and the personal preference of the operator as to the nature of the enterprise to be conducted are factors which would tend to retard accentuation of commodity cycles even though the farm building was highly flexible. (p. 117)

23. Notable work has been done by the Midwest Plan Service in the development of farm building plans incorporating features of flexibility. Only moderate enthusiasm has been manifest on the part of farm structures
specialists and farmers relative to features tending to promote increased flexibility within farm structures.

(pp. 126-127)
SUMMARY

Farm buildings represent the second largest capital investment in American agriculture being surpassed only by the value of the land itself. Furthermore, maintenance and repair expenditures, plus outlays for new construction, amount to many millions of dollars annually. From the standpoint of yearly operating costs on most farms, buildings represent a rather small fraction of the total cost schedule when compared with such cost factors as feed and labor. The economic importance of farm buildings as an input factor lies in the heavy demands which they represent on the capital resources of the farmer.

Agricultural engineers and agricultural economists alike have stressed the importance of farm buildings from an economic standpoint but have neglected to present appropriate models or advance hypotheses on which a better understanding of them as production factors might be grasped. The clarification and delineation of production theory appropriate to farm buildings has been the primary goal of this study.

The analyses are restricted to the farm as a profit maximizing unit. Certain limitations peculiar to the field of agricultural economics are cited at the outset including
lack of knowledge of:

1. Building input-output relationships
2. Optimum division of the total building outlay between competing enterprises
3. Relationship between fixed costs and unit costs of production at varying levels of output

The following factors in the field of agricultural engineering are cited but not considered in the analyses:

1. Planning problems occasioned by the relatively long life of farm buildings as compared with the brief average tenure period for farm operators
2. Slowness with which new and improved designs and methods of construction are translated to the field
3. Shortage of qualified workers in the farm structures field

Yearly capital inputs are computed for two alternative arrangements for dairy and swine housing. Employing a going interest rate of five per cent, the analysis indicates the increasing magnitude of the input as anticipated returns are projected over the life of a short-lived versus a long-lived building. The significance of an assumed daily saving in labor is demonstrated and the possibility presented that this feature might well be the deciding factor in the making of recommendations between long- and short-lived buildings.
Following a brief treatment of the importance of capital rationing the analysis is repeated considering a capital productivity rate in agriculture taken arbitrarily as 12 per cent. This procedure lends increased emphasis to the high cost of yearly capital inputs when projected over the life expectancy of a long-lived building as compared with a shorter-lived one even though the original annual capital input in the latter may be substantially higher.

Assumed building production functions are used to indicate by means of a derived transformation curve, the marked difference which will exist in the division of building resources between enterprises by two farmers with different amounts of available building capital. The implications of the analysis suggest that the flexible building arrangement is of more importance to the farmer with limited building capital than in the case of the farmer with greater resources.

The division of building investment between competing enterprises is considered employing both long- and short-run concepts. Two enterprises are arbitrarily selected and based first on decreasing returns, and secondly on increasing returns to the building investment, the optimum division of building resources is determined based on historical price ratios. Relationships between the short- and long-run planning curves are emphasized particularly with regard to
the flexible and inflexible plants.

Building flexibility is considered in detail in the final section. Short-run planning curves between the hog and poultry enterprises are derived based essentially on established space requirements. The inflexibility of the small poultry housing unit is compared with the relative flexibility of the central type hog housing unit. The analysis considers in the first instance the case of a farmer with moderate building resources and secondly the farmer with limited building capital. Practical aspects of flexibility are indicated including the stable relationship which likely exists between hog and poultry production on Iowa farms producing hogs as a main enterprise.

Activities of the Midwest Plan Service relating to the provision of increased flexibility in farm building designs are reviewed. A specific example is given. Work of this kind may well be a point of departure from which increased flexibility in farm buildings may be ultimately achieved.
LITERATURE CITED


23. Hanson, G. B. Farm building costs and appraisals. Agricultural Engineering 17:413-16, 422. 1936.


ACKNOWLEDGMENTS

Throughout the course of the investigation the farmers of the Gilbert, Iowa, Community, neighbors of the writer, have been very helpful in presenting their views relative to the contribution of farm buildings to their particular production programs.

Professor Henry Giese has been of great assistance through his constant attitude of optimism and encouragement at times when the progress of the study seemed very slow or altogether static. His advice based on wide experience and a thorough understanding of the farm structures field has been most valuable.

The interest of Dr. Earl O. Heady in farm buildings as a factor in agricultural production was an important factor in originating the study. From his profound knowledge of the whole of the field of production economics the writer has gleaned much.

Special acknowledgment is also due Professor Hobart Beresford, Dr. W. G. Murray, Professor Robert A. Caughey, and Professor Norval H. Curry. These gentlemen have been particularly helpful throughout the course of the study.

Finally, I wish to mention the constant encouragement and cooperation received from my wife, Peggy Bower Lanham.
ALTERNATE ROOF SHAPE

NOTE: IF THE BARREL ROOF IS DESIRED AS SHOWN IN ALTERNATE ABOVE, ORDER MIDWEST PLAN NO. 72006-C FOR CONSTRUCTION DETAILS.

Figure 34

MIDWEST PLAN SERVICE

GENERAL PURPOSE BARN

FLOOR AND FOUNDATION PLAN

SCALE 4'-0" / 1'-0"
Iroha All Xg = RIDGE COLLA BEAMS SIDING RAKE DETAIL SCALE r=1'-0"

6 SHEET METAL SUTTER

SYMMETRICAL ABOUT STOP

ROOFING AS DESIGNED OVER SHEATHING

LAMINATED BLUE REED RAYS

ROOFING AC CURED OVER SHEETMETALS

2-1/2" C.C. BOLTUP OR SOLVENT

2-1/2" STRIPS DROP ONE LAMINATION AT EACH OF THE FOLLOWING LEVELS ABOVE THE SILL LINE: 10'-0", 12'-0", 16'-0", AND 20'-0'.

NOTE FOR BALE Storage, DOUBLE JOISTS IN OUTER SPANS AND INCREASES TO 5'-0" GIRDERS TO 5'-2" X 2"

2 X 12 HEADER DETAIL

TSG FLOORING CLIP ANGLE LAG EOLT SILL

3-2 X 12 CONTINUOUS LINTEL BRIDGING

3-2" X 12" GIRDER 2 JOISTS 2-0 O.C

2-2 X 6 SILL 1/2" X 1/2" ANCHOR BOLTS 9 6'-0" O.C

WALL SECTION AT WINDOW

MIDWEST PLAN SERVICE

GENERAL PURPOSE BARN

5111 1 SHEET 2 OF 4 SHEETS

MIDWEST PLAN NO. 72136
**ISOMETRIC OF Farrowing Pens**

**NOTES**

- INSTALL 3/4" O.D. PIPE INSERTS 2-5/8" OFF LONGITUDINAL GRID LINES AS SHOWN ON PLAN IN SHEET ONE. HOLES ARE 3-1/2" X 4-1/2".
- PROVIDE ENOUGH 3/4" PIPE CONNECTORS FOR ORIGINAL SETUP. ADD MORE CONNECTORS AND "FURNITURE" AS CHANGES ARE MADE.
- CASE MUST BE TIGHT DURING CONSTRUCTION THAT FACES OF JOISTS OCCUR DIRECTLY ABOVE GRID LINES.

**COMPOSITE BARN PLAN**

COMPOSITE PLAN SHOWS SPACE UTILIZATION. IT IS NOT INTENDED TO REPRESENT AN IDEAL PLAN.

**Figure 37**

**GENERAL PURPOSE BARN**

**ALTERNATE CORNICE**

**FLOOR CONNECTION**

**SCALE 1"=1'-0"**

**COOPERATIVE DIVISION WORK IN AGRICULTURAL AND HORTICULTURAL PLANS PREPARED BY**

- A.M. LAND CITY BARN
- M.A. LAND CITY BARN
- A.M. LAND COUNTRY PLAN
- M.A. LAND COUNTRY PLAN
- A.W. LAND COUNTRY PLAN
- M.W. LAND COUNTRY PLAN

**GENERAL PURPOSE BARN**

- B1/4 SHEET 4 OF 4 SHEETS
- MIDWEST PLAN NO. 72136