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DEVELOPING AN APPROPRIATE GRAIN STORAGE SYSTEM

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DEVELOPING AN APPROPRIATE GRAIN STORAGE SYSTEM*

by Dale G. Anderson**

I. Background

Of the three basic requirements for human survival and fulfillment--food, clothing, and shelter--food needs are perhaps most frequently and most tragically unmet. It is not that present world supplies of food are inadequate, but rather that distribution of these supplies is highly unequal. Some areas experience shortages while others have surpluses. A given area may have shortages in one season or year, surpluses in the next.

Storage is a critical factor in alleviating these imbalances, and food grains are the staple and major storable food commodity. Storage of food grains can fulfill one or more of three important objectives:

1) Storage is needed to meet postharvest consumption requirements. Harvest periods may occur only once or twice per year, but the day-to-day need for food persists.

2) A dependable source of stored grain can moderate seasonal price fluctuations, providing farmers as well as consumers with more stable prices. Inadequate storage systems penalize farmers who must sell at harvest time and consumers who must continue to buy several months hence. The essential nature of the staple food grains causes their price to be

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highly sensitive to relatively small changes in supply. A relatively small buffer stock can be an effective price moderating tool.

3) Storage can provide for emergency needs occasioned by poor harvests. Undependable weather patterns in Sub-Sahara Africa create a particular need for emergency reserves in this area.

In short, it is the periodicity and variability of harvests which create the need for storage. Growth in grain production, population, and real incomes are bringing ever increasing storage needs. And the needs are becoming ever more complex and more challenging to fulfill. New grain varieties not only yield more, but tend also to produce grain that is more susceptible to damage from stored grain insects. Short-season varieties grown under newly developed irrigation schemes may produce two or more harvests per year, with one or more of these harvests occurring during rainy seasons. Drying the grain and keeping it dry under such conditions present new and challenging problems in many areas.

Increasing population and urban development are forcing changes in storage activities. Larger proportions of larger total amounts of grain must be moved beyond a formerly closed system involving farm production, farm storage, and farm-family consumption. Storage must be provided in appropriate forms and places as the grain moves from farms toward urban consumers.

It is evident that present storage procedures and facilities in many areas are less than adequate for the task at hand. Estimates of losses occurring during storage vary widely and most are based on expedient measurement procedures, but losses in some areas are generally agreed to be quite large. Estimates for semi-arid Africa range from 10 to 75 percent. Assuming a loss of 25 percent and a price of $71 per metric ton, the loss for the

1971 crop would have been 27 million tons, or more than US $1 billion.[1] Estimates of losses usually account only for loss of weight and therefore may underestimate total economic loss. It is more difficult to estimate losses of nutritional value, losses occasioned by ingestion of mycotoxins, losses from impaired germination of stores held for seed, or milling losses stemming from contamination of grain with stones or other foreign material.

While the magnitude of available loss estimates is suggestive of extensive economic waste, it is well to stress that physical losses do not necessarily correspond with economic losses. If the costs incurred in alleviating losses of grain during storage exceed the value of the lost grain, there is no economic rationale for action. To put it another way, efforts aimed at reducing grain losses should not cost more than the saved grain is worth. Some losses are inevitable; the cost of totally eliminating losses in most circumstances would be far greater than the value of the marginal grain saved.

II. The Postharvest System

It is essential to recognize, in the location, design, and management of grain storage facilities, that storage is part of a larger system of economic activity. Storage is only one of three basic functions performed between the time grain is harvested and the time it is consumed. Storage provides what economists term time utility or time value. Storage of grain from harvest until the time it is needed by consumers constitutes a valuable service. Those who store grain--farmers, cooperatives, merchants, millers, government agencies, or others--incur costs, costs which must be recovered

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[1]Spurgeon, David, Hidden Harvest: A Systems Approach to Postharvest Technology, IDRC-062e (Ottawa: International Development Research Center, 1976), p. 9.

from higher grain prices when the grain is finally sold if there is to be an incentive to provide such storage.

The second important function of the marketing system is the provision of place utility or place value. Grain must be transported from where it is harvested to where it is finally needed by consumers. Those who provide transport services must also recoup their expenses if they are to continue in business.

Finally, grain must be transformed from its raw form into a form acceptable to consumers. Wheat may be milled into flour; rice may be hulled and polished; maize, millet or sorghum ground into meal or flour. Form utility or form value are the labels given the service provided by this function. The costs of such processing must be recovered in the markups between the price paid by the processor and the price charged for the final product.

Sometimes two or more of these three functions are performed by a single participant in the system. A farmer may store maize and later transport it to a local market. A flour miller must have some minimal amount of storage space for both wheat and flour. Grain is sometimes stored in rail wagons for lengthy periods.

The various postharvest activities are interconnected--physically by transportation and storage links, institutionally by pricing mechanisms. There are numerous trade-offs within the system. The timing of the major transportation tasks depends on whether storage is oriented toward producing or consuming areas. Storage at one location can substitute for storage at another. Storage of one type can substitute for that of another. Government storage schemes can substitute for on-farm storage and vice versa. Storage of raw grain can substitute for storage of grain products. Whether trucks carry wheat or flour from rural collection and storage centers to

urban markets depends on where the mills are located. Where harvest periods occur at different times in different areas, transportation can substitute for storage and vice versa. Grain can either be stored in local areas to meet local needs or shipped from areas of temporary surplus to meet needs of areas experiencing temporary deficits, and vice versa when deficit-surplus patterns reverse with the progression of harvests. The result of these interactions is that action taken at any point in the system is likely to have effects on other elements within the system.

The need for considered attention to these interrelationships is greatest in a planned economic environment or in an imperfectly competitive environment. The need for such attention is diminished to the extent that the system is comprised of highly competitive elements although, here too, it is important that the rules under which participants in the system operate be designed to preserve the competitive environment. The need for a government role is apparent, too, where grain moves in international channels. Moreover, there are subsystems of economic activity within the larger national or international postharvest systems. A privately owned and operated flour mill requires storage activities to complement its basic milling function and requires transportation services for both wheat and flour. In the long run, optimal location of the mill will be affected directly by storage and transport options and their costs. In the short run, mill efficiency will be affected by grain assembly, storage, and flour disposition options. The manager of the mill must consider these interactions as investment and operational decisions are made.

The postharvest system and its subsystems are becoming larger and much more complex because their tasks are becoming larger. Increasing grain production and increasing urbanization have meant that much more grain must be

marketed and ultimately moved to more distant consumers. Rising consumer incomes have increased demand for grain and for marketing services. Urban consumers today rarely want raw grain. They want flour or baked goods instead of wheat. They want polished rice rather than paddy. They don't want insect contamination, and they don't want musty or moldy products. Resulting demands upon the marketing system are growing much faster than growth in grain production.

The interrelated nature of the various storage, transport, and processing elements in the postharvest system and the growing size and complexity of the system suggest the desirability of a unified approach toward the planning of the respective elements. Such an approach is available and operational in a computerized postharvest system for feasibility analysis developed at Kansas State University (KSU).[2] The nature, capabilities, and data requirements of the KSU model are described briefly in Section III, below.

In recognition of the necessarily complex nature of a model which is aimed at optimization of a highly complex system, and of the need in many instances to make both long-run and short-run decisions without benefit of a total systems model, some general guidelines for systems improvement are discussed in Section IV.

III. A Computerized Model for Improved System Planning

The KSU computerized system for feasible agribusiness development is an operational system which has been applied to grain marketing problems in

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[2]A detailed discussion of the approach is found in Richard Phillips, Leonard W. Schruben, and Joe M. Tiao, User's Guide to Computerized System for Feasible Agribusiness Development; Volume One: Text and Charts, Food and Feed Grain Institute Special Report No. 2 (Manhattan, Kansas: Kansas State University, 1975). A complete listing of the required computer programs is contained in Volume Two: Computer Programs. (Manhattan: Kansas State University, 1975).

several different countries. Its purpose is the economic evaluation of a country's postharvest handling system and the measurement of net benefits from alternative system elements. The computerized system is comprised of a series of linked subprograms which can be run individually or as a coordinated system. A schematic diagram of major system elements is found in Figure 1. Four basic groups of data input are required:

1) investment and income data for modular farm and agribusiness production units
2) market potentials--consumption survey, population, and family income data
3) agricultural resource and yield data
4) transportation, storage, and marketing system links.

The data are analyzed in a series of linked computer programs to establish the costs of alternative production activities; the level and nature of demand for farm products, consumer foods, and farm inputs; the production potentials for farm output; and least-cost transportation-processing-storage networks. The results of these analyses provide the bases for further analyses which lead to the development of programs for the agricultural sector and an overall agribusiness development plan. The net benefits from alternative feasible modular production units representing alternative types (technologies), number, size, location, and timing are evaluated given optimum routing of transported farm inputs and products. The total system is optimized in the sense that the best combination of evaluated alternatives is determined. The sensitivity of final solutions to small changes in the makeup of modular production units can be tested.

Central to the computerized system is a "transportation-type" linear programming (LP) model. Constraints imposed in the LP model include market

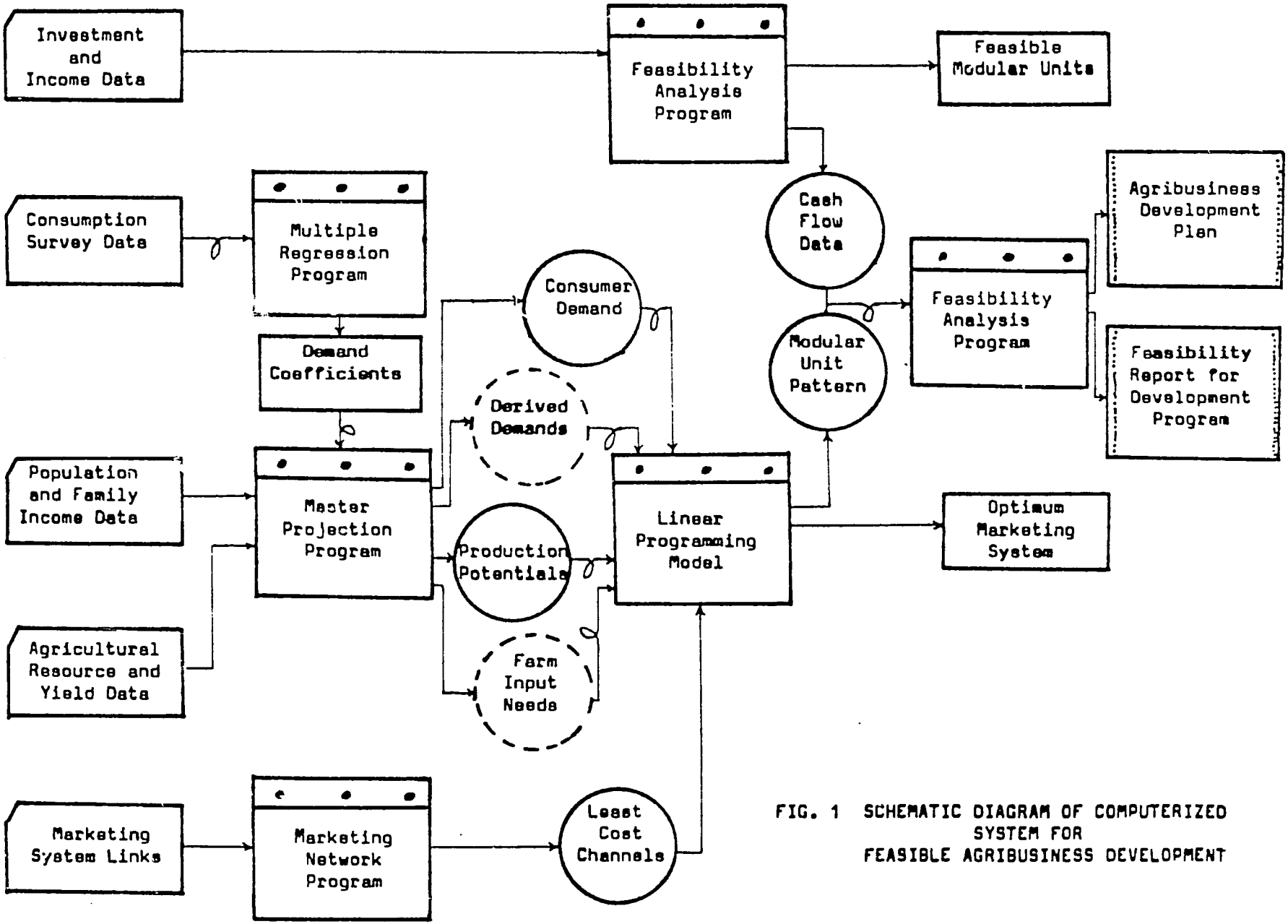

FIG. 1 SCHEMATIC DIAGRAM OF COMPUTERIZED SYSTEM FOR FEASIBLE AGRIBUSINESS DEVELOPMENT

Source: Richard Phillips, Leonard W. Schruben, and Joe M. Tiao, User's Guide to Computerized System for Feasible Agribusiness Development; Volume One: Text and Charts, Food and Feed Grain Institute Special Report No. 2 (Manhattan, Kansas: Kansas State University, 1975), p. 2-4.

and production potentials for agricultural products and state of development of physical and social infrastructure. The four basic data sources outlined previously form the basis for the LP optimization runs.

The first step in preparation for the LP evaluations is development of modules or modular production and marketing units. The modules are structured based on actual performance of existing efficient enterprises in the area (if they exist) or elsewhere (if they don't). Computerized prototypes of these selected enterprises provide the basis for testing the impact of new technology, organizational changes, managerial innovation, or other selected changes. Discounted cash flow data for the modular units are developed from investment and operating costs and income estimates. "Feasible" units are developed based on results of a feasibility analysis program which requires data describing:

1) facilities costs,
2) working capital,
3) projected revenues, and
4) projected operating costs.

The patterns of existing modular unit organization or proposed development must be defined in terms of their type, number, size, location, and timing. All cash flows, costs as well as revenues, are discounted to measure the internal rate of return (IRR) of total capital invested in the enterprise or the social rate of return (SRR). General discounting procedures are outlined in Appendix A.

The second major analytical step is the projection of market potentials for consumer and intermediate products. Demand coefficients are calculated based on consumption data from household surveys or historical time series. Market potential projections are based on demand coefficients,

population projections, and real income projections. Consumer demand coefficients and base period consumption patterns are combined with population and family income data by municipality in a master projection program which yields market level projections of net demand for consumer and intermediate products.

The third step is projection of agricultural crop and livestock potentials and resulting input requirements. Projections are made, using a master projection program, from historical data on the agricultural resource base--crop hectarages by land and water control classification, projected yields and other production coefficients. Regression analysis is used to project expected future hectarage, yield and total crop production. Separate runs are made to account for soil types, irrigation, and other differences across geographic areas. Wet season vs. dry season production patterns as well as seasonal harvesting patterns are estimated. Input requirements can be read from the production projections by application of appropriate conversion factors.

The fourth and final step prior to making the LP optimization runs is establishment of the least-cost marketing network. Data on marketing system costs and capacities are evaluated in a marketing network program and other programs in establishing least-cost marketing channels. The least-cost combination of transport, storage, and processing is determined, given capacity limitations in the system. Proposed changes in the system and their effect upon costs can also be evaluated.

The LP model is used in selecting the optimum marketing system for each commodity and farm input for a given time period, based on the projected production and market demand patterns and the least-cost marketing channels. Separate computer runs are made for each time period. Runs are made in which

the existing system is compared with systems incorporating proposed improvements in transportation networks, storage networks, and processing networks. Shadow prices suggest which improvements are needed and when. A series of runs is required to establish the optimal number, location, and timing pattern of modular units.

The overall goal of the analysis is one of building a balanced and efficient agribusiness system in support of integrated area development. Resource needs of the resulting system are identified or implied, including:

1) capital investment and financing,
2) human resource development,
3) market promotion and demand creation, and
4) supporting services.

The program generates the following financial information concerning prospective or indicated system changes:

1) the internal or direct rate of return on total capital investment,
2) the financial rate of return on equity capital,
3) the economic impact upon the area (associated or social rate of return), and
4) the net cash flow for the system.

The great advantage of the computerized approach is its ability to search out quickly and precisely the optimal combinations of large numbers of actual and proposed system variables. While the computer is infallible in the precision with which it evaluates data inputs, great discretion must be exercised by the investigator in the selection and modeling of alternatives. Results of the analysis can be no more reliable than the data employed in the analysis.

IV. Some General Guidelines for System Improvement

While a total systems approach to questions of facility size, type, location, and timing clearly has much merit, it is not always feasible to undertake such a detailed analysis. It is therefore useful to consider some shortcuts which might be taken toward optimum system design. There are a number of common-sense propositions which are valuable guides to grain storage planning, propositions which should be recognized by anyone involved in storage planning whether with or without the benefit of a computerized analytical model. Although the intended emphasis of this discussion is on storage, the important interractions among storage, transportation, and the various processing activities make it both difficult and undesirable to confine attention to storage alone. The present section therefore deals directly with the relevant trade-offs among these functions.

The procedural steps followed in the computerized model are also appropriate for a less rigorous analysis. For example, in assessing the need for new or improved facilities, estimates of future grain production and consumption are needed at a minimum. Past trends are often the best guide, with allowances for major expected departures from trend such as irrigation developments, changes in government pricing policies, or the like. It is important to account for relevant changes in consumer purchasing patterns and in rural-urban population balances and trends.

The same discounted cash-flow techniques which form the basis for computerized evaluation and selection from among alternative system investments are appropriate for use by farmers, cooperatives, private merchants, or government agencies in planning for storage activities. The formulas outlined in Appendix A need not be solved with a computer if the objective is to compare discounted net benefits from alternative storage investments.

Transport routing is often no problem at the local level. There often is only one obviously feasible route. A farmer may have a single market for his grain. A grain merchant may know from experience where and how and when to market his purchases. And even at the national level, the relevant options may be few.

The same general principles apply to decisions affecting either local or national level postharvest systems. The objective in any case is to maximize the net positive difference between total discounted benefits and total discounted costs. Benefits from national policies, however, are sometimes difficult to measure. The value to consumers or to grain producers of greater price stability stemming from storage programs is not easy to quantify. The humanitarian benefits from availability of an emergency reserve during years of short crops are perfectly clear, but their quantification in economic terms poses troublesome problems.

Assuming that the purpose for grain storage is to meet people's basic requirements for food, total storage facilities throughout the system must be at least equal to average crop size plus carry-over from the previous crop year plus an allowance for year-to-year variations in crop size. In fact, there must be sufficient storage for at least an entire crop of unmilled grain. The greater storability of rough rice or unmilled wheat or maize as compared with milled grain products, along with the need for storage to house the new crop of unmilled grain as it is harvested, suggest the need in most instances for only limited amounts of storage for milled rice, flour, and other grain products. At a minimum, an amount of milled grain sufficient to keep the pipeline to consumers from running dry is required.

If reserve stocks are held, total storage requirements may be much greater, with the need for milled grain stores possibly being somewhat

larger also. The mix of reserve, between paddy and milled rice, and between wheat and flour, will vary with milling capacity, expected rate of emergency consumption, and accessibility of consumers to the mills. Since relatively modest production variability may translate to relatively large variability in marketings, the amount of storage space required may vary greatly. Facilities to meet the average need are not sufficient in many years, but will far exceed requirements in other years. Facilities large enough to meet storage requirements in years of maximum production may be very costly to own and operate given the much lower level of average utilization. Imports might be stored in facilities normally used for domestic production during poor crop years, or later in each marketing year when domestic stocks have been drawn down, but these facilities may be badly "out of position" for imports. Using port facilities for storage of local production may or may not make sense, depending on location of the port relative to local surplus and deficit grain areas. The additional transportation costs incurred to store domestic grain in such facilities may or may not be offset by savings from dual usage. Storage facilities for imported stocks at least large enough to accommodate one incoming ship are usually required since the transport "pipeline" from port to inland points is often too small or too undependable to permit direct transfer of grain from ship to trucks, rail wagons or other conveyance.

Storage to accommodate peak-year crops may not be required if short-term temporary storage is feasible. Storage out of doors on pallets and under plastic film or tarpaulins may be a good alternative where climate permits. Substandard stores or warehouses normally used for other purposes may be pressed into temporary grain storage. Grain in temporary storage should be withdrawn first and as quickly as milling requirements permit.

While the guidelines for optimization of storage (and related transport and processing) activities may be relatively straightforward, there is evidence that they are often violated. Examples of misplaced or mal-designed storehouses stand, often unused or underused, as monuments to the misguided efforts of many a grain storage "improvement" project. Nor are individual entrepreneurs, guided as they may be by the dictates of competitive pressures, immune from making costly mistakes. A few observations about how the total postharvest system interacts may prevent our losing sight of the larger picture as we make decisions affecting pieces of the system. Some of the comments to follow have relevance primarily for government planners, others are aimed at individual decision-makers.

Farmers, merchants, or other individuals or business firms need some assurance that they will profit from building and operating grain storage facilities. The issue is whether, on average, grain prices will rise sufficiently to offset the costs of storage, including capital investment outlays and all other fixed and variable costs. Major cost items are depreciation; interest (costs of borrowed capital or foregone interest on equity); property taxes; losses of quantity and quality of grain; maintenance of the storage facility; labor for filling, managing and emptying the facility; and fumigation and insecticides.

A convenient way to appraise the feasibility of constructing a storehouse is to (1) estimate the average historical postharvest price increase per ton, (2) subtract all estimated storage costs per ton <u>except</u> interest and depreciation, and (3) discount resulting net benefits from storage over the expected life of the storehouse at the appropriate rate of interest. The resulting present value of storage serves as a basis for deciding whether a proposed new facility should or should not be built, or for deciding which,

if any, alternative facilities should be built. The following example may make the procedure more clear (Appendix A has additional details).

Consider a hypothetical case involving a decision as to whether to construct a new storage facility in an area not now having such a facility. The potential supply of grain in the area has been determined to be adequate to support the needs of a warehouse of about 400 metric tons. A survey of consumer demand also indicates the need now and in the future for increased storage. A site has been selected, costs have been budgeted, and price trends analyzed to establish expected storage margins.

Cost of the prospective 400MT storage facility is projected at $40/MT, or a total of $16,000. Expected life of the plant is 15 years, with zero salvage value at the end of the period. Annual fixed costs (labor, management, insurance, plant upkeep) are estimated at $1,000. Variable costs (interest on grain inventories, fumigation, insecticides, losses) are estimated at $5.00 per ton of throughput with an assumed two turns of inventory per year. Interest and depreciation costs are not included in cash flows since they are part of the cost of capital (whether borrowed or owned) and are accounted for directly in the discounting process of the cash flow analysis. Projected sales margins are $9.00 per ton for each turn or $7,200 per year for a fully-utilized facility.

Four steps are required to evaluate the feasibility of the proposed investment using the present-value technique (results are summarized in Table 1):

1) Selection of a discount rate. The discount rate is a measure of opportunities foregone by investing in the proposed facility. It is usually the firm's cost of borrowed capital.

2) Organize the cash flows on an annual basis. Costs and benefits

TABLE 1

PRESENT VALUE OF NET CASH FLOWS
FOR A HYPOTHETICAL GRAIN STORAGE FACILITY

Year	(1) Costs*	(2) Revenues**	(3) Net Cash Flows	(4) 10% Discount Factor	(5) Present Value of Flows
0	$16,000		-$16,000	1.00	-$16,000
1	5,000	$7,200	2,200	.909	2,000
2	5,000	7,200	2,200	.826	1,817
3	5,000	7,200	2,200	.751	1,652
4	5,000	7,200	2,200	.683	1,503
5	5,000	7,200	2,200	.621	1,366
6	5,000	7,200	2,200	.564	1,241
7	5,000	7,200	2,200	.513	1,129
8	5,000	7,200	2,200	.467	1,027
9	5,000	7,200	2,200	.424	933
10	5,000	7,200	2,200	.386	849
11	5,000	7,200	2,200	.350	770
12	5,000	7,200	2,200	.319	702
13	5,000	7,200	2,200	.290	638
14	5,000	7,200	2,200	.263	579
15	5,000	7,200	2,200	.239	526
					+$732

*Exclusive of cost of grain.

**Sales margin -- grain sales price minus purchase price multiplied by number of tons handled.

must be estimated for each year of the facility's life. Grain purchase costs and sales prices need not be entered into the calculations if the interest costs of holding the inventory are included separately. Expected margins (markup of sales price over purchase price) are the benefits.

3) Calculation of net present values for each year. Net cash flows (column 1 minus column 2 in Table 1) are summed for each year and multiplied by the appropriate discount factor for that year (from Appendix Table A-1) to obtain present value.

4) Present values for all years are summed. A negative result indicates an unprofitable investment. A positive net present value indicates the investment will yield a return greater than the cost of capital. There may, of course, be other investments which would yield a still higher rate of return. There may not be enough capital available to undertake all profitable investments.

Net benefits in the example are $732, indicating that the project is feasible. In other words, net returns are $732 higher than if capital had been invested in an alternative yielding a 10 percent return on investment.

A contrasting example will illustrate the importance of the timing of the cash flows and of use of the discounting procedure. Assume that a more costly building can be constructed but with the advantage that it will be more convenient to fill and to empty. The alternative building costs $18,000 to construct, but labor and management costs are reduced by $200 per year. Over a 15-year life, total labor and management costs would be reduced by $3,000. Thus, for an additional $2,000 initial outlay, $3,000 in labor and management costs are saved. At first sight the "improved" building seems to be the logical choice. However, when the costs and benefits are discounted over the 15 years, a different picture emerges (Table 2). The project is

TABLE 2

PRESENT VALUE OF NET CASH FLOWS
FOR A HYPOTHETICAL "IMPROVED" GRAIN STORAGE FACILITY

Year	(1) Costs*	(2) Revenues**	(3) Net Cash Flows	(4) 10% Discount Factor	(5) Present Value of Flows
0	$18,000		-$18,000	1.00	-$18,000
1	4,800	$7,200	2,400	.909	2,182
2	4,800	7,200	2,400	.826	1,982
3	4,800	7,200	2,400	.751	1,802
4	4,800	7,200	2,400	.683	1,639
5	4,800	7,200	2,400	.621	1,490
6	4,800	7,200	2,400	.564	1,354
7	4,800	7,200	2,400	.513	1,231
8	4,800	7,200	2,400	.467	1,121
9	4,800	7,200	2,400	.424	1,018
10	4,800	7,200	2,400	.386	926
11	4,800	7,200	2,400	.350	840
12	4,800	7,200	2,400	.319	766
13	4,800	7,200	2,400	.290	696
14	4,800	7,200	2,400	.263	631
15	4,800	7,200	2,400	.239	574
					+$252

*Exclusive of cost of grain.

**Sales margin -- grain sales price minus purchase price multiplied by number of tons handled.

still feasible, but present value of the "improved" alternative is only $252 ($252 higher than an investment returning 10 percent). Present value of the original project was $732, or $480 above that of the alternative.

It is well to stress that it has been assumed that the proposed grain storehouse will be filled twice per year and that grain will be stored until such time that the price has increased by $9.00 per metric ton. A relatively small decrease either in grain margins or in the amount of grain stored would make the storage project unprofitable. The relatively high variability of annual grain production in Sub-Sahara Africa implies an even greater variability in annual storage needs and opportunities. Reference to Appendix Table A-2 indicates that the present value of $1.00 received each year for 15 years at a discount rate of 10 percent is $7.61. This means that for each $1.00 per year of reduced revenue (net of reductions in variable costs occasioned by declining inventory value), present value of the investment will decline by $7.61. In the above example of a $16,000 facility, a $100 per year decline in net revenues is more than enough to make the project unfeasible. A $100 increase in annual costs will have the same effect.

Moreover, $16,000 is a rather modest cost for a 400-ton facility. Such a low cost implies use of local construction materials and techniques. Since the $16,000 investment must be made at the beginning of the 15-year life of the facility, the present value of each $1.00 of investment is $1.00, and so a $732 increase in investment costs will make the project infeasible at a 10 percent rate of discount.

Present value of an investment is very sensitive to the size of the investment. It cannot be stressed too strongly that the rate at which facilities involving large fixed investments are utilized is a very important factor in the success of the investment. Imported grain storing, handling,

and processing technologies are almost always more capital intensive than locally-available technologies in the developing countries. These imported technologies may be very efficient in developed countries where labor and other operating costs are high relative to the cost of capital. Such technologies may be economical in developing countries as well, but the relatively high fixed costs which they imply must be spread over a large volume of stored grain if they are to be competitive with less capital-intensive technology.

An alternative analytical procedure is one in which the present costs of a storage facility plus storage stocks are estimated in order to determine the annual net benefits (expected seasonal price rise minus all costs exclusive of interest and depreciation), over alternative planning periods and rates of discount, required to make the investment pay out. The annual benefits per $100 of current investment needed to justify the investment, at alternative discount rates and time periods, are summarized in Appendix Table A-3. The table can be used in either of two ways: (1) to estimate the payout period; that is, the number of years of required storage use to make the investment profitable, or (2) to estimate the annual benefits required to make a facility profitable given the length of its expected useful life.

In the previous example of a $16,000 facility holding 400MT of grain with expected receipts of 800MT per year benefits, over a 15-year life at a discount rate of 10 percent, must be $13.15 per year per $100 of investment, or $2,104 per year. The implicit assumption, when this procedure is used, is that net benefits (net of all non-capital costs) are the same each year over the life of the investment, a condition which is not likely to prevail. Thus, while reference to Appendix Table A-3 may give a quick and general indication of benefits needed to justify a storage investment, the present-value approach is preferable.

A third approach, the one used in the KSU systems analysis, is to compute the discounted rate of return (internal rate of return for commercial investments, social rate of return for public projects) which a proposed investment or series of alternatives will earn. This approach is somewhat more complicated, and we will not delve into it here; but it does have considerable merit as it indicates the precise differences in projected profitability of alternative investments.

Size of Facilities

The relative importance of facility size (and location) decisions is related to the level in the system at which decisions are being made. Farmers, for example, are faced with the question of whether to build or not to build storage facilities to hold marketable surplus grain for deferred sale. Size of the facility, however, is an issue clearly subsidiary to the question of whether to build at all. Nor is location an important issue; if built at all, the farm store will probably be located in or near the farm house where the grain will be convenient and secure.

Size and location are critical concerns, however, in the planning of centralized collection facilities. Storage facilities at such collection points are normally much larger than on-farm stores and the potential range of size much greater as well. The consequences of a sizing error are therefore of considerable significance. The more important considerations in the sizing of a centralized storage facility include:

1) Present and anticipated monthly pattern of farmers' marketings for each grain. Storage needs are reduced where two or more crops per year are harvested. The pattern will depend on the on-farm storage situation as well as on harvest patterns. A relatively even flow of incoming grain will reduce the need for centralized storage and increase the potential utilization

of receiving facilities and storage space, particularly if outshipments from the central facility follow a similar even pattern.

The expected size and variability of farmers' marketings relative to projected consumer demands are critical factors in the sizing of strategic reserves. Greater variability calls for larger reserves. The appropriate size of reserves depends on other variables as well, such as expected availability of international stocks, and is too complex an issue for discussion at this time.[3]

2) Density of farmers' grain marketings. Higher densities of grain marketings (MT/km^2, bu/mi^2, etc.) in the area surrounding the storage facility reduce the average travel distance required to assemble a given amount of grain and therefore make larger volumes available and larger facilities feasible. Procedures for relating average travel distance to densities of grain marketings are outlined in Appendix B.

3) Cost of grain assembly. The average cost per mile or kilometer of travel by local means of transportation determines the maximum feasible farm-to-market distance. Practical considerations such as the round-trip distance which can be travelled in a single day may also be important. The maximum feasible farm assembly distance for paddy rice has been estimated at 10km for manual transport, 25km for animal or bicycle transport. However, permanent stores or buying stations with procurement radii much less than 25 or 30km have proved to be very costly in some countries. Grain marketing densities are rarely sufficient to support such a diffused collection system.

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[3]A detailed procedure for sizing reserve stocks is discussed in Richard Phillips and L. Orlo Sorenson, Food Grain Reserves in Developing Countries, Food and Feed Grain Institute Special Report No. 6 (Manhattan, Kansas: Kansas State University, 1978), 81 pp.

Mobile buying teams which rotate among several pickup sites on a regular schedule are one alternative, particularly in providing flexibility in meeting exceptional harvest needs. Increased transportation efficiency and reduced transfer costs increase the feasible grain assembly distance and associated plant size.

4) Monthly pattern of outshipments for each grain. The need for storage at the collection facility will be affected by the timing of grain flows to mills or other storage points. The more even the flows over time, the lower will be the storage requirements, except in the unlikely case where an irregular pattern of outflows is matched by the same pattern of inflows. In most cases, the outshipments will coincide closely with the relatively constant pattern of consumer requirements.

5) Cost of delivering grain to processors or consumers. Transport costs to processors have more impact on plant location than on size, although the two issues are not separable. Larger plants are likely to have a mill or consumer orientation and therefore have lower delivery costs. On the other hand, a small plant located in a production area may be oriented toward supplying local needs, with resulting low delivery costs. Larger plants may have lower delivery costs owing to larger shipment sizes. Truck-load and rail wagon-load rates are normally lower than partial-load rates. Rates for multiple loads in single shipments may be lower still.

6) Costs of storage and processing. There are usually economies of scale associated with each function of the post-harvest system. Storage, drying, cleaning, transportation, and milling can often be performed at lower cost per unit in relatively large-scale facilities. In some cases, technology differs by scale of operations. Equipment such as driers may be available only in certain sizes; the smallest size may be too large for

on-farm or other small-scale employment. A large rice milling operation might also support an oil extraction plant, but 25 tons or so per hour of paddy processing capacity would be required--a very high rate.

On-farm or other small-scale storage or processing activities may be at a disadvantage for all of the above reasons. On the other hand, the close personal supervision and the direct personal incentive of the owner-operator of the small enterprise may be major advantages. Managing a large facility employing large numbers of people is a totally different proposition than overseeing a small one. Scale economies of processing and storage may be offset by higher assembly costs, and by higher delivery costs if a high proportion of the grain must return to the producing area. Higher labor costs in urban areas and loss of weight and bulk in processing are factors arguing for decentralization. Furthermore, milling by-products are frequently more valuable (as livestock feeds) in rural areas than in cities.

A final, and probably most important, aspect of scale economies is that large-scale facilities are designed to accommodate large quantities of grain. Total investment costs of larger facilities are invariably greater than for smaller ones, investment costs per ton are often larger also because of the scale-technology relationship alluded to earlier. Large-scale technology imported from developed countries is almost invariably capital-intensive technology; fixed costs tend to be high relative to variable costs. Thus, a large-scale plant must be operated at a high level of output. A large storage facility must be used to store a very large volume of grain. Under-utilization of large facilities can be economically disastrous.

Size requirements and building capabilities must be evaluated carefully. For instance, aisles must be left between stacks and around the perimeter of a large bag-storage building. No more than 60 to 75 percent of a building's

volume normally is available as storage space.[4] Costs must be estimated accurately and evaluated realistically. The present-value (or related internal or social rate of return) method outlined previously is the preferred means for making cost comparisons among alternative facility sizes.

Processing facilities must be coordinated with storage so as to avoid bottlenecks. Driers, for example, must be large enough to accommodate the flow of grain from harvest until such time as economic losses from deterioration of the wet grain would exceed benefits from larger drier capacity. In any event, drying capacity need not be as great as grain receiving capacity since a drier can be operated 24 hours per day. The sizing problem is complicated by the fact that both production and grain moisture content are often highly variable from one harvest to the next.

7) Existing facilities. Facilities already in place must be identified and evaluated. The private storage operator must account for his competitors' storage capabilities as well as his own. The effective density of marketings to any one facility in an area will be reduced to the extent that some of the grain goes to other facilities. Facilities substandard for regular use might be useful for meeting peak loads and should be accounted for.

Location of Facilities

Optimal location of facilities is a matter first of orientation with respect to grain supplies and demands, and second of specific site selection. Site selection considerations include the following:[5]

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[4]T. O. Hodges and Harry B. Pfost, Grain Handling, Storage and Marketing Short Course Outlines, Section C; Handling, Conditioning and Storage, Food and Feed Grain Institute Manual No. 2 (Manhattan, Kansas: Kansas State University, 1977), p. IV-25.

[5]Adapted from Richard Phillips, Managing for Greater Returns in Grain, Feed and Other Retail Businesses Serving Agriculture, 3rd Edition (Manhattan, Kansas: Ag Press, 1970), p. 344.

1) Transportation facilities. Availability of a rail siding may be the first requirement in many countries, particularly if grain must be shipped more than 100 or so miles. Ready access to a good all-weather highway is often equally important, depending on whether rail service is available and on relative rail/truck rates if there is rail service. Motor carriers tend to have competitive rates for shorter hauls. Inland water transport is often the lowest cost form of transport, where available, for long distances.

2) Convenience to customers, workers, and management. A site located near a trade center, providing easy highway access for customers and employees, is essential.

3) Availability of power source. Electric power is needed, or at least highly desirable, for centralized facilities. Small diesel generating units are usually a relatively costly source of electricity.

4) Congestion. The facility should be located near a trade center, but not within it. Highway access should provide for an orderly flow of incoming customers.

5) Drainage. Since part of the facility may be underground, it is essential that the site be high and dry.

6) Available land. The cost of land and the amount of it available are obvious considerations. Sufficient land should be acquired to allow for possible future expansion.

7) Bed rock or other footing. The great weight of a large storehouse filled with grain requires attention be given to footing conditions. Pile driving will be required where existing support is not adequate.

8) Availability of grain. This issue was addressed previously in the "size" section. The relatively high fixed cost of grain storage facilities makes it imperative that facilities be utilized as fully as possible.

The location of grain storage and processing facilities is usually oriented toward either grain producers or the consuming public. However, it is probably essential in most cases that some facilities be located in each area. Where imports or exports are part of the flow picture, port facilities will also be required. The major location considerations include:

1) Transport availability and costs. Other things being equal, grain should be stored on or near the farm since the discounted present value of transport costs is reduced by delaying shipment as long as possible. Delaying shipments until they are required for consumption also distributes the shipments evenly over time, thereby avoiding peak-load problems. The transportation system may, however, be carrying other products which have seasonal shipping patterns; resulting bottlenecks might be reduced by timing grain and grain products shipments so as to avoid these peaks, but that might require an otherwise uneconomical combination of origin and destination stores.

2) Existing storage and processing patterns. The fulfillment of unmet needs is the major consideration in fitting new facilities into the pattern of existing storage and processing facilities. Complementary relationships should also be exploited. Handling costs can be minimized, for example, by locating storage space adjacent to mills, thus avoiding transshipment from store to mill or from mill to store. Relatively large storage facilities are sometimes located as an adjunct to milling operations to assure a dependable source of grain for the mills. Modern mills, and modern rice mills in particular, tend to have relatively high fixed costs, a condition which places a premium on full utilization of the fixed facilities. Sometimes storage is built, even though the storage by itself would not be profitable, because of this complementary storage-milling relationship. Rice mills in Panama and in the Philippines have large storage adjuncts because, although government

policies and overbuilding of commercial storage facilities have led to low storage margins, rice supplies over time have tended not to be dependable. Storage losses are more than offset by lower milling costs associated with improved utilization of the mills.

3) Costs of storage and processing at alternative locations. Costs may vary by location because of differences in resource prices or differences in storage conditions. Labor costs, for example, may be lower in rural locations than in urban areas. Scale economies might be realized, however, from locating large facilities near urban deficit areas which require large volumes of products. Where storage costs are the same at production or at consumption locations, facilities should be located near the source of production since delaying shipment will result in a lower discounted present value of transportation costs.

4) Regional production and consumption patterns. Transportation as well as storage costs are saved by supplying current local consumption needs from current production from the same area. Whether it is better for a given locality to store its own grain production to meet postharvest needs or to trade grain with another area whose harvest occurs at a later time, depends on the relative costs of storage and transport. Other things equal, facilities housing grain which ultimately moves back to the areas from which it was collected should be smaller and oriented more toward production sources than facilities which serve the needs of urban or other deficit areas.

5) Climate. Increasing temperature, humidity, and rainfall have adverse effects on storability of grain. Insect and mold problems are related directly to these variables. Lower grain moisture content is required for successful storage, but is harder to attain at higher levels of temperature and relative humidity. Some countries have a great variety of micro

climates resulting from differences in elevation, latitude, or prevailing wind patterns. Storage sites in drier, cooler areas should be chosen, where possible.

Climate also affects road conditions. Grain must not be stored where adverse road conditions will prevent its being transported to where it is needed when it is needed. Areas which become temporarily inaccessable during rainy seasons must have their own product storage or their own mills and grain stores. Where weather conditions create the need for artificial driers, drying facilities will normally have to be production oriented since high moisture grain must be dried promptly in warm climates. Production-oriented driers will require complementary production-oriented grain receiving and holding facilities as well.

6) Product characteristics. Since a significant loss of weight occurs in the milling of most grain products, it is ordinarily less costly to transport the end product than the grain. While less storage space is required to hold milled products than grain, the former are much less storable as their shelf lives tend to be relatively short. Moreover, storage space sufficient to hold an entire crop of grain is required to accommodate the harvest; building product storage would not greatly reduce the need for grain storage. Storing grain and delaying processing until required for consumption also results in a lower discounted present value of processing costs.

Type of Facilities

The type of facilities most appropriate for a particular installation depends on such factors as purpose for the stores, the amount of grain to be stored, stage of development of the marketing system, and costs of alternative stores. Purpose is the first consideration. Long-term storage--strategic reserves, for example--requires less sophisticated loading and

unloading equipment since the grain will be handled infrequently. Such facilities must be built with careful attention to control of moisture, insects, and rodents, however.

If long-term storage is for bulk grain, "flat" construction will probably be adequate and much less costly than upright silos. The issue centers on a trade-off between the relatively higher total fixed costs for the upright facility versus the relatively higher average variable costs for the flat facility. The volume of grain moving through an upright facility must be great enough, perhaps several "turns" per year, to reduce average fixed costs to a level competitive with costs for a flat facility. More careful attention must be given to maintaining grain in good condition in a long-term storage facility. Protection against damage from insects, rodents, and molds must be given high priority.

Average storage costs can be reduced by building multiple-use facilities. Farm supplies, for example, can be stockpiled as grain supplies are drawn down. Care must be exercised in making sure quality of the grain is not jeopardized; toxic chemicals should not be stored in the same building with grain. Multiple-use facilities are normally designed for bag storage of grain, although it is possible to construct flat bulk storage with adjustable bulkheads which provide multiple-commodity flexibility.

Amount of grain to be stored is an important "type" factor. Economies of scale dictate larger facilities for larger volumes rather than a series of smaller units, although smaller units can be constructed one at a time as the need arises. Scale economies in bulk storage appear to be much more significant than in bag storage, even though a single bag store can accommodate several lots of grain, while a bulk bin can house only one lot. At least three bins per class of grain stored are generally needed. The number

of lots of bagged grain to be stored at one time and the sequence of their arrival and departure have a bearing on appropriate size and type of facility. Unless multiple lots stored in a single building are to be removed simultaneously, the building must be designed to allow their removal in sequence.

Facility type and size are closely related factors. Economies of scale stem in some instances from improved technologies available only in larger scale units. The basis for village-level storage as a substitute for on-farm stores is the improved facilities and specialized management afforded by the centralized stores. These consolidated stores, which may operate as cooperatives or under government direction or supervision, can be effective in reducing physical losses during storage. They can enable farmers to benefit from rising postharvest prices and, by reducing losses, increase the size of marketable surplus. Village-level stores can be particularly effective in areas where climate makes on-farm storage difficult and where local demands absorb most of the production.

Grain storage facilities should be in character with the rest of the marketing system. If mills are equipped only for handling bagged grain and if trucks and rail wagons haul only bagged grain, construction of bulk storage facilities would probably be a mistake as the extra costs of emptying and filling bags, in and out of storage, would probably offset any savings from bulk storage.

Proper coordination of the facilities with the rest of the system reduces to a matter of costs. Locally available labor and construction materials are important factors in appropriate design. For example, low-cost local labor can build stores from locally-produced concrete blocks. The resulting structure is likely to be more durable and lower in cost than the prefabricated metal imports which have become so common in so many

places. Savings in foreign exchange and support of local construction trades are further reasons for using local resources.

Facility choice should be guided also by the nature of the local transport network and services. Receiving and outloading accommodations appropriate for local transport are needed. In some cases no local storage at all may be the appropriate solution. Country collection points may be an economical alternative to production-oriented storage facilities where marketing densities are relatively low, economies of storage size relatively great, and economies of size in transport relatively great. Grain might be collected into trucks, eliminating the need for local storage.

Pricing Considerations

Appropriate pricing policies are essential to the evolution of an efficient grain marketing system, at least where private decision-makers such as farmers, merchants, millers, truckers, and consumers have any role at all. If storage is to play its role in providing time utility, transport its role of place utility, and processing its role in form utility, prices must be allowed to vary in each of these dimensions--time, space, and form.

There is a tendency for government-sponsored or operated grain marketing agencies to overlook the role of prices in allocating production resources and in the distribution of benefits between and within producer and consumer groups. Transportation cost pooling is practiced in some countries by government grain marketing boards which collect grain at the farm or at village or other local collection points. While such a practice may be helpful in developing markets in remote locations having considerable potential for surplus production, it has adverse implications as well. Absorbing freight costs for distant producers leads to an uneconomical allocation of

production resources. It is better in the long run to work toward reducing unit costs of transportation than to subsidize distant producers through cost equalization. If a government procurement agency is in competition with private traders, the traders are likely to capture grain nearest to main market centers, leaving the government with the higher-cost distant production.

The seasonal nature of production requires that grain be stored to meet the more regular needs of consumers. Prices should increase through the course of the postharvest period, but only enough to cover storage costs so long as stocks are adequate to meet consumer needs. Effective grain storage programs can be helpful in reducing inter-seasonal price variability. There must be sufficient competition in the performance of the storage function, however, if excessive postharvest price increases are to be avoided. A major purpose for government-sponsored storage programs is provision of such competition.

Finally, it is important that prices for differences in product form reflect costs of milling or other processing. It is important that price differences for differences in product quality reflect consumers' valuation of these differences. A good system of government-sponsored grades and standards will provide incentive for all participants of the marketing system, from farmers through retailers, to maintain quality standards at a cost which consumers are willing to pay. Administered processing margins must be set at levels which cover all costs including an allowance for replacement of buildings and equipment. The government must ensure that there is sufficient competition to keep competitively-established margins in line with costs.

V. Summary, Implications

Grain storage problems in developing countries are becoming increasingly critical. Losses during storage are generally believed to be excessive. Factors contributing to the problem are increasing grain production, rising population, urbanization, growth in real incomes, adoption of crop varieties susceptible to stored grain insects, and increased double cropping.

Storage, transportation, and processing activities are part of an interrelated system of postharvest activities. Changes in one part of the system have effects on other elements in the system; storage development plans should account for these interractions.

Ideally, a rigorous systems analysis should be applied in planning for storage improvements. A computerized approach for such planning is available. There are, however, numerous "common-sense" guidelines which are helpful in avoiding serious errors in planning for storage facility size, location, type, and pricing. Size considerations include:

1) Storage space is needed for the nation as a whole to house an average crop plus carryover and an allowance for year-to-year crop variability. Additional storage for imports may also be needed. Most of the storage should be for unmilled grain.

2) Larger scale storage and processing facilities are often more efficient than smaller ones, but must be utilized intensively if economies are to be realized. Larger plants have higher grain assembly costs which are an offset to the scale economies.

3) Higher densities of marketable grain make larger collection facilities feasible.

4) Transportation improvements make larger collection facilities feasible. Larger collection facilities may permit larger and more efficient

shipments to mills. Reductions in transportation costs may lead to reductions in storage costs and vice versa.

5) An even flow of grain over time from farms to collection points and from collection points to mills results in reduced need for storage at collection points and mills.

6) Temporary facilities or dual use of facilities for farm supplies and grain or for imported grain and local grain may obviate the need for having facilities large enough to hold extraordinarily large harvests.

7) Existing facilities must be accounted for in any evaluation of need for new storage space. Poorer facilities or facilities normally used for other purposes might serve as temporary grain storage in emergencies.

Major location considerations involve (1) specific site selection and (2) orientation of the facilities with respect to consumers on the one hand and grain producers on the other. Major site selection factors are access to transportation, power source and availability of an adequate amount of low-cost, well-drained land with good footing for the required load. Availability of sufficient grain is, of course, a first requirement. Basic location considerations include:

1) Access to least-cost modes of transportation is highly important.

2) New facilities must be meshed with the pattern of existing storage and processing activities. Complementary as well as competitive relationships may exist.

3) Storage and processing costs at alternative locations must be compared.

4) Costs of local storage to meet local needs must be compared with costs of exchanging grain with other localities having different harvest periods.

5) Facilities should be located, where feasible, in areas having climatic conditions best suited to grain storage.

6) Processing weight losses make production-oriented processing and associated storage attractive. Resulting gradual movement of products from producing areas to deficit regions minimizes the discounted value of transportation and processing costs and reduces the likelihood of transportation bottlenecks.

7) Grain stored in producing areas can never be "out of position"; transport costs are thereby minimized. Some grain products are needed for consumption in rural areas in any event. Reshipment of grain or products from distant central stores to rural consumers would increase transport costs. Storage in both areas would diminish opportunities to exploit scale advantages.

8) Orientation of facilities toward consumers avoids the risk that bad roads or other transport problems might prevent shipments when needed.

9) If a requirement exists for commercial drying, storage in producing areas will be needed to complement drying activities.

Some important facility-type considerations include:

1) Long-term storage facilities need less efficient receiving and load-out systems but better grain protection provisions than short-term stores. "Flat" facilities are the usual choice for long-term bulk storage, upright facilities for large-volume, short-term bulk storage.

2) Designing facilities for multiple use can reduce costs, but care must be taken not to contaminate grain with toxic materials.

3) Size and type are interrelated factors. A large structure ordinarily is more efficient than a replication of smaller ones. The latter, however, may prove to be a more flexible arrangement.

4) Storage facilities should match with the rest of the system. Bagged

systems of transport and milling usually call for bagged storage as well.

5) Local construction labor and materials should be used where possible.

Appropriate pricing policies can be effective in guiding the development of postharvest systems. Pricing policies which take account of the time value created by storage, the place value of transportation, and the form value by processing will encourage timely and "correct" investments in these activities.

The guidelines reduce to comparisons of discounted costs and benefits of alternative changes in the system. Since improved efficiency in one element of the system may affect efficiency elsewhere, maximization of total system benefits net of costs is the basis for evaluating prospective changes.

APPENDIXES

APPENDIX A

CASH-FLOW DISCOUNTING RATIONALE AND PROCEDURES

Income received at some point in the future is worth less to the recipient than if it were received in the present period since present income can be put to work earning interest payments or placed in an alternative income-earning investment. Costs incurred in the future are likwise less costly than if incurred in the present.

Since the present value of a future stream of income or costs is less than the future value of the flows, the value of the flows must be discounted by an appropriate rate of interest if the true net values of alternative enterprise investments are to be properly compared. The following relationships form the basis for the discounting procedure. Rate of return on a capital investment is given by:

$$A_1 = A_o + A_o r$$

where A_1 = value a year from now

A_o = present value

r = annual interest rate

therefore, $A_1 = A_o(1 + r)$

and $A_o = A_1/(1 + r)$

and, generalizing for n years,

$$A_n = A_o(1 + r)^n$$

or, for a stream of annual income over n years, the formula for the discounted present value of the stream is:

$$V_A = A_o + A_1/(1 + r) + A_2/(1 + r)^2 + \ldots + A_n/(1 + r)^n$$

where, V = present value of the income stream

A_i = income flows in respective years

r = discount rate

Investment and operating costs can be similarly discounted to determine the present value of a series of expenditures over time:

$$V_I = I_o + I_1/(1 + r) + I_2/(1 + r)^2 + \ldots + I_n/(1 + r)^n$$

The present values of $1.00 received n years hence, and at alternative rates of discount, are summarized in Appendix Table A-1. Where cash flows in all years are identical, Appendix Table A-2 can be used in calculating the present value of the flows. Appendix Table A-3 can be used to estimate the payout period of a proposed investment or to estimate the annual benefits required to make a facility profitable.

APPENDIX TABLE A-1

PRESENT VALUE OF $1

Year hence	1%	2%	4%	6%	8%	10%	11%	12%	13%	14%	15%	16%	17%	18%	20%	22%	24%	25%	30%	35%	40%	45%	50%
1	0.990	0.980	0.962	0.943	0.926	0.909	0.901	0.893	0.885	0.877	0.870	0.862	0.855	0.847	0.833	0.820	0.806	0.800	0.769	0.741	0.714	0.670	0.667
2	0.980	0.961	0.925	0.890	0.857	0.826	0.812	0.797	0.783	0.769	0.756	0.743	0.731	0.718	0.694	0.672	0.650	0.640	0.592	0.549	0.510	0.476	0.444
3	0.971	0.942	0.889	0.840	0.794	0.751	0.731	0.712	0.693	0.675	0.658	0.641	0.624	0.609	0.579	0.551	0.524	0.512	0.455	0.406	0.364	0.328	0.296
4	0.961	0.924	0.855	0.792	0.735	0.683	0.659	0.636	0.613	0.592	0.572	0.552	0.534	0.516	0.482	0.451	0.423	0.410	0.350	0.301	0.260	0.226	0.198
5	0.951	0.906	0.822	0.747	0.681	0.621	0.593	0.567	0.543	0.519	0.497	0.476	0.456	0.437	0.402	0.370	0.341	0.328	0.269	0.223	0.186	0.156	0.132
6	0.942	0.888	0.790	0.705	0.630	0.564	0.535	0.507	0.480	0.456	0.432	0.410	0.390	0.370	0.335	0.303	0.275	0.262	0.207	0.165	0.133	0.108	0.088
7	0.933	0.871	0.760	0.665	0.583	0.513	0.482	0.452	0.425	0.400	0.376	0.354	0.333	0.314	0.279	0.249	0.222	0.210	0.159	0.122	0.095	0.074	0.059
8	0.923	0.853	0.731	0.627	0.540	0.467	0.434	0.404	0.376	0.351	0.327	0.305	0.285	0.266	0.233	0.204	0.179	0.168	0.123	0.091	0.068	0.051	0.039
9	0.914	0.837	0.703	0.592	0.500	0.424	0.391	0.361	0.333	0.308	0.284	0.263	0.243	0.225	0.194	0.167	0.144	0.134	0.094	0.067	0.048	0.035	0.026
10	0.905	0.820	0.676	0.558	0.463	0.386	0.352	0.322	0.295	0.270	0.247	0.227	0.208	0.191	0.162	0.137	0.116	0.107	0.073	0.050	0.035	0.024	0.017
11	0.896	0.804	0.650	0.527	0.429	0.350	0.317	0.287	0.261	0.237	0.215	0.195	0.178	0.162	0.135	0.112	0.094	0.086	0.056	0.037	0.025	0.017	0.012
12	0.887	0.788	0.625	0.497	0.397	0.319	0.286	0.257	0.231	0.208	0.187	0.168	0.152	0.137	0.112	0.092	0.076	0.069	0.043	0.027	0.018	0.012	0.008
13	0.879	0.773	0.601	0.469	0.368	0.290	0.258	0.229	0.204	0.182	0.163	0.145	0.130	0.116	0.093	0.075	0.061	0.055	0.033	0.020	0.013	0.008	0.005
14	0.870	0.758	0.577	0.442	0.340	0.263	0.232	0.205	0.181	0.160	0.141	0.125	0.111	0.099	0.079	0.062	0.049	0.044	0.025	0.015	0.009	0.006	0.003
15	0.861	0.743	0.555	0.417	0.315	0.239	0.209	0.183	0.160	0.140	0.123	0.108	0.095	0.084	0.065	0.051	0.040	0.035	0.020	0.011	0.006	0.004	0.002
16	0.853	0.728	0.534	0.394	0.292	0.218	0.188	0.163	0.141	0.123	0.107	0.093	0.081	0.071	0.054	0.042	0.032	0.028	0.015	0.009	0.005	0.003	0.002
17	0.844	0.714	0.513	0.371	0.270	0.198	0.170	0.146	0.125	0.108	0.093	0.080	0.069	0.060	0.045	0.034	0.026	0.023	0.012	0.006	0.003	0.002	0.001
18	0.836	0.700	0.494	0.350	0.250	0.180	0.153	0.130	0.111	0.095	0.081	0.069	0.059	0.051	0.038	0.028	0.021	0.018	0.009	0.005	0.002	0.001	0.001
19	0.828	0.686	0.475	0.331	0.232	0.164	0.138	0.116	0.098	0.083	0.070	0.060	0.051	0.043	0.031	0.023	0.017	0.014	0.007	0.003	0.002	0.001	0.000
20	0.820	0.673	0.456	0.312	0.215	0.149	0.124	0.104	0.087	0.073	0.061	0.051	0.043	0.037	0.026	0.019	0.014	0.012	0.005	0.002	0.001	0.001	0.000
21	0.811	0.660	0.439	0.294	0.199	0.135	0.112	0.093	0.077	0.064	0.053	0.044	0.037	0.031	0.022	0.015	0.011	0.009	0.004	0.002	0.001	0.000	0.000
22	0.803	0.647	0.422	0.278	0.184	0.123	0.101	0.083	0.068	0.056	0.046	0.038	0.032	0.026	0.018	0.013	0.009	0.007	0.003	0.001	0.001	0.000	0.000
23	0.795	0.634	0.406	0.262	0.170	0.112	0.091	0.074	0.060	0.049	0.040	0.033	0.027	0.022	0.015	0.010	0.007	0.006	0.002	0.001	0.000	0.000	0.000
24	0.788	0.622	0.390	0.247	0.158	0.102	0.082	0.066	0.053	0.043	0.035	0.028	0.023	0.019	0.013	0.008	0.006	0.005	0.002	0.001	0.000	0.000	0.000
25	0.780	0.610	0.375	0.233	0.146	0.092	0.074	0.059	0.047	0.038	0.030	0.024	0.020	0.016	0.010	0.007	0.005	0.004	0.001	0.001	0.000	0.000	0.000
30	0.742	0.552	0.308	0.174	0.099	0.057	0.044	0.033	0.026	0.020	0.015	0.012	0.009	0.007	0.004	0.003	0.002	0.001	0.000	0.000	0.000	0.000	0.000
35	0.706	0.500	0.253	0.130	0.068	0.036	0.026	0.019	0.014	0.010	0.008	0.006	0.004	0.003	0.002	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000
40	0.672	0.453	0.208	0.097	0.046	0.022	0.015	0.011	0.008	0.005	0.004	0.003	0.002	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
45	0.639	0.410	0.171	0.073	0.031	0.014	0.009	0.006	0.004	0.003	0.002	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
50	0.608	0.372	0.141	0.054	0.021	0.009	0.005	0.003	0.002	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Source: Frank J. Smith, Jr., and Ken Cooper, The Financial Management of Agribusiness Firms, Special Report 26 (St Paul: University of Minnesota and U.S. Department of Agriculture, 1967), p. 55.

Prepared by Henry Hwang, Research Specialist, Department of Agricultural Economics, University of Minnesota.

APPENDIX TABLE A-2

PRESENT VALUE OF $1 RECEIVED ANNUALLY AT THE END OF EACH YEAR FOR N YEARS

Year (N)	1%	2%	4%	6%	8%	10%	11%	12%	13%	14%	15%	16%	17%	18%	20%	22%	24%	25%	30%	35%	40%	45%	50%
1	0.990	0.980	0.962	0.943	0.926	0.909	0.901	0.893	0.885	0.877	0.870	0.862	0.855	0.848	0.833	0.820	0.807	0.800	0.769	0.741	0.714	0.690	0.667
2	1.970	1.942	1.886	1.833	1.783	1.736	1.713	1.690	1.668	1.647	1.626	1.605	1.585	1.566	1.528	1.492	1.457	1.440	1.361	1.289	1.225	1.165	1.111
3	2.941	2.884	2.775	2.673	2.577	2.487	2.444	2.402	2.361	2.322	2.283	2.246	2.210	2.174	2.107	2.042	1.981	1.952	1.816	1.696	1.589	1.493	1.407
4	3.902	3.808	3.630	3.465	3.312	3.170	3.102	3.037	2.975	2.914	2.855	2.798	2.743	2.690	2.589	2.494	2.404	2.362	2.166	1.997	1.849	1.720	1.605
5	4.853	4.714	4.452	4.212	3.993	3.791	3.696	3.605	3.517	3.433	3.352	3.274	3.199	3.127	2.991	2.864	2.745	2.689	2.436	2.220	2.035	1.876	1.737
6	5.796	5.601	5.242	4.917	4.623	4.355	4.231	4.111	3.998	3.889	3.785	3.685	3.589	3.498	3.326	3.167	3.021	2.951	2.643	2.385	2.168	1.983	1.824
7	6.728	6.472	6.002	5.582	5.206	4.868	4.712	4.564	4.423	4.288	4.160	4.039	3.922	3.812	3.605	3.416	3.242	3.161	2.802	2.508	2.263	2.057	1.883
8	7.652	7.326	6.733	6.210	5.747	5.335	5.146	4.968	4.799	4.639	4.487	4.344	4.207	4.078	3.837	3.619	3.421	3.329	2.925	2.598	2.331	2.109	1.922
9	8.566	8.162	7.435	6.802	6.247	5.759	5.537	5.328	5.132	4.946	4.772	4.607	4.451	4.303	4.031	3.786	3.566	3.463	3.019	2.665	2.379	2.144	1.948
10	9.471	8.983	8.111	7.360	6.710	6.145	5.889	5.650	5.426	5.216	5.019	4.833	4.659	4.494	4.193	3.923	3.682	3.571	3.092	2.715	2.414	2.168	1.965
11	10.368	9.787	8.761	7.887	7.139	6.495	6.207	5.938	5.687	5.453	5.234	5.029	4.836	4.656	4.327	4.035	3.776	3.656	3.147	2.752	2.438	2.185	1.977
12	11.255	10.575	9.385	8.384	7.536	6.814	6.492	6.194	5.918	5.660	5.421	5.197	4.988	4.793	4.439	4.127	3.851	3.725	3.190	2.779	2.456	2.197	1.985
13	12.134	11.348	9.986	8.853	7.904	7.103	6.750	6.424	6.122	5.842	5.583	5.342	5.118	4.910	4.533	4.203	3.912	3.780	3.223	2.799	2.469	2.205	1.990
14	13.004	12.106	10.563	9.295	8.244	7.367	6.982	6.628	6.303	6.002	5.725	5.468	5.229	5.008	4.611	4.265	3.962	3.824	3.249	2.814	2.478	2.210	1.993
15	13.865	12.849	11.118	9.712	8.560	7.606	7.191	6.811	6.462	6.142	5.847	5.576	5.324	5.092	4.676	4.315	4.001	3.859	3.268	2.826	2.484	2.214	1.995
16	14.718	13.578	11.652	10.106	8.851	7.824	7.379	6.974	6.604	6.265	5.954	5.669	5.405	5.162	4.730	4.357	4.033	3.887	3.283	2.834	2.489	2.216	1.997
17	15.562	14.292	12.166	10.477	9.122	8.022	7.549	7.120	6.729	6.373	6.047	5.749	5.475	5.222	4.775	4.391	4.059	3.910	3.295	2.840	2.492	2.218	1.998
18	16.399	14.992	12.659	10.828	9.372	8.202	7.702	7.250	6.840	6.468	6.128	5.818	5.534	5.273	4.812	4.419	4.080	3.928	3.304	2.844	2.494	2.219	1.999
19	17.226	15.679	13.134	11.158	9.604	8.365	7.839	7.366	6.938	6.550	6.198	5.878	5.585	5.316	4.844	4.442	4.097	3.942	3.311	2.848	2.496	2.220	1.999
20	18.046	16.352	13.590	11.470	9.818	8.514	7.963	7.470	7.025	6.623	6.259	5.929	5.628	5.353	4.870	4.460	4.110	3.954	3.316	2.850	2.497	2.221	1.999
21	18.857	17.011	14.029	11.764	10.017	8.649	8.075	7.562	7.102	6.687	6.313	5.973	5.665	5.384	4.891	4.476	4.121	3.963	3.320	2.852	2.498	2.221	2.000
22	19.661	17.658	14.451	12.042	10.201	8.772	8.176	7.645	7.170	6.743	6.359	6.011	5.696	5.410	4.909	4.488	4.130	3.971	3.323	2.853	2.499	2.222	2.000
23	20.456	18.292	14.857	12.304	10.371	8.883	8.267	7.718	7.230	6.792	6.399	6.044	5.723	5.432	4.925	4.499	4.137	3.976	3.325	2.854	2.499	2.222	2.000
24	21.244	18.914	15.247	12.551	10.529	8.985	8.348	7.784	7.283	6.835	6.434	6.073	5.747	5.451	4.937	4.507	4.143	3.981	3.327	2.855	2.499	2.222	2.000
25	22.024	19.524	15.622	12.784	10.675	9.077	8.422	7.843	7.330	6.873	6.464	6.097	5.766	5.467	4.948	4.514	4.147	3.985	3.329	2.856	2.499	2.222	2.000
30	25.808	22.397	17.292	13.765	11.258	9.427	8.694	8.055	7.496	7.003	6.566	6.177	5.829	5.517	4.979	4.534	4.160	3.995	3.332	2.857	2.500	2.222	2.000
35	29.409	24.999	18.665	14.498	11.655	9.644	8.855	8.176	7.586	7.070	6.617	6.215	5.858	5.539	4.992	4.541	4.164	3.998	3.333	2.857	2.500	2.222	2.000
40	32.835	27.356	19.793	15.047	11.925	9.779	8.951	8.244	7.634	7.105	6.642	6.234	5.871	5.548	4.997	4.544	4.166	3.999	3.333	2.857	2.500	2.222	2.000
45	36.095	29.490	20.720	15.456	12.109	9.863	9.008	8.283	7.661	7.123	6.654	6.242	5.877	5.552	4.999	4.545	4.166	4.000	3.333	2.857	2.500	2.222	2.000
50	39.197	31.424	21.482	15.762	12.234	9.915	9.042	8.305	7.676	7.133	6.661	6.246	5.880	5.554	4.999	4.545	4.167	4.000	3.333	2.857	2.500	2.222	2.000

Source: Frank J. Smith, Jr., and Ken Cooper, The Financial Management of Agribusiness Firms, Special Report 26 (St Paul: University of Minnesota and U.S. Department of Agriculture, 1967), p. 60.

Prepared by Henry Hwang, Research Specialist, Department of Agricultural Economics, University of Minnesota.

APPENDIX TABLE A-3

ANNUAL $ BENEFITS REQUIRED OVER PERIODS OF 1 TO 20 YEARS
TO JUSTIFY CURRENT INVESTMENT OF $100, DISCOUNT RATES 8 TO 20 PERCENT

Benefit Periods (Years)	Discount Rate (Percent)												
	8	9	10	11	12	13	14	15	16	17	18	19	20
1	108.00	109.00	110.00	111.00	112.00	113.00	114.00	115.00	116.00	117.00	118.00	119.00	120.00
2	56.08	56.85	58.39	58.39	59.17	59.95	60.73	61.51	62.30	63.08	63.87	64.66	65.45
3	38.80	39.51	40.21	40.92	41.64	42.35	43.07	43.80	44.53	45.26	45.99	46.73	47.47
4	31.19	30.87	31.55	32.23	32.92	33.62	34.32	35.03	35.74	36.45	37.17	37.90	38.63
5	25.05	25.71	26.38	27.06	27.74	28.43	29.13	29.83	30.54	31.26	31.98	32.71	33.44
6	21.63	22.29	22.96	23.64	24.32	25.02	25.72	26.42	27.14	27.86	28.59	29.33	30.07
7	19.21	19.87	20.54	21.22	21.91	22.61	23.32	24.04	24.76	25.49	26.24	26.99	27.74
8	17.40	18.07	18.74	19.43	20.13	20.84	21.56	22.29	23.02	23.77	24.52	25.29	26.06
9	16.01	16.68	17.36	18.06	18.77	19.49	20.22	20.96	21.71	22.47	23.24	24.02	24.81
10	14.90	15.58	16.27	16.96	17.70	18.43	19.17	19.93	20.69	21.47	22.25	23.05	23.85
11	14.01	14.69	15.40	16.11	16.84	17.58	18.34	19.11	19.89	20.68	21.48	22.29	23.11
12	13.27	13.97	14.68	15.40	16.14	16.90	17.67	18.45	19.24	20.05	20.86	21.69	22.53
13	12.65	13.36	14.08	14.82	15.57	16.34	17.12	17.91	18.72	19.54	20.37	21.21	22.06
14	12.13	12.84	13.57	14.32	15.09	15.87	16.61	17.47	18.29	19.12	19.97	20.82	21.69
15	11.68	12.41	13.15	13.91	14.68	15.47	16.28	17.10	17.94	18.78	19.64	20.51	21.39
16	11.30	12.03	12.78	13.55	14.34	15.14	15.96	16.79	17.64	18.50	19.37	20.25	21.14
17	10.96	11.70	12.47	13.25	14.05	14.86	15.69	16.54	17.40	18.27	19.15	20.04	20.94
18	10.67	11.42	12.19	12.98	13.79	14.62	15.46	16.32	17.19	18.07	18.96	19.87	20.78
19	10.41	11.17	11.95	12.76	13.58	14.41	15.27	16.13	17.01	17.91	18.81	19.72	20.65
20	10.19	10.95	11.75	12.56	13.39	14.24	15.10	15.98	16.87	17.77	18.68	19.60	20.53

Source: Adapted from Richard Aplin and George L. Casler, Evaluating Proposed Capital Investments with Discounted Cash Flow Methods, Second Ed., (Ithaca, New York: Department of Agricultural Economics, Cornell University, 1969), pp. A-8 and A-9.

APPENDIX B

GRAIN ASSEMBLY DISTANCE/DENSITY RELATIONSHIPS

The following relationships are useful in estimating average distance travelled in assembling a given volume of grain to a central collection point, given a known density of grain marketings. It is assumed that the grain collection point is located at the center of a circular assembly territory, that grain marketings are evenly distributed over the territory, and that transportation to the central collection point is in a straight line. The area of the circular assembly territory is given by

$$A = \pi r^2$$

where A = area (expressed as mi^2, km^2, or other area measure)

$\pi = 3.1416$

r = radius of the circle

and, therefore

$$r = \sqrt{A/\pi}$$

The radius of the circular territory required to assemble a given volume of grain is given by

$$r = \sqrt{V/\pi D}$$

where V = total volume of grain marketed

D = marketing density (MT/km^2, bu/mi^2, or other measure)

The average one-way travel distance is approximated by[6]

$$\bar{r} = 2/3\sqrt{V/\pi D}$$

Since road networks ordinarily do not permit travel in a straight line from

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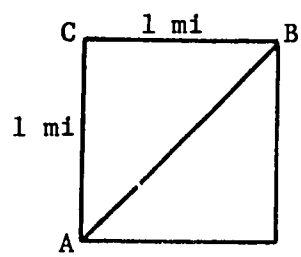
[6]Fred L. Olson, "Location Theory as Applies to Milk Processing Plants," Journal of Farm Economics, Vol. 41, No. 5 (December, 1959), pp. 1546-59.

farm to collection point, a correction factor, k, is needed to account for the resulting increased distance. A sample of actual travel distances can be taken and an average regression of actual distance to $\bar{r}$ calculated. Alternatively, where road networks follow a regular pattern, the relationship between actual and straight-line distance can readily be estimated. For example, the effect of a rectangular grid road network, having road intersections one mile apart, and with collection plant located at a road intersection, is approximated by a correction factor derived from the Pythagorian Theorem. The maximum increased distance involved in following the grid road system is the difference between travelling from point A to point B in a straight line on the one hand and travelling by way of point C on the other hand, in the diagram below:



$$(AB)^2 = (AC)^2 + (CB)^2$$

$$AB = \sqrt{(AC) + (CB)}$$

$$= \sqrt{1 + 1}$$

$$= \sqrt{2}$$

$$= 1.414$$

But, since not all of the travel from farm to collection point involves travelling both one-mile legs of the triangle ABC, the actual correction factor is closer to 1.207, making the corrected average travel distance

$$\bar{r} = 2/3(k)\sqrt{V/\pi D}$$

with $k = 1.207$

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