Staff Papers Series

Staff Paper P91-49

November 1991

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[1] Prepared as part of cooperative agreement number 58-3AEM-8-00114 between the University of Minnesota and the U.S. Department of Agriculture Economic Research Service.

Staff papers are published without formal review within the Department of Agricultural and Applied Economics. Ge Backus, Mike Boehlje, Dick Epley, Harold Guither, John Lawrence, and Jerry Shurson provided helpful comments on earlier drafts. As usual, any remaining errors or omissions are the responsibility of the authors.

Economics of Some Swine Production Systems With Reference to Animal Welfare

Executive Summary

The purpose of this study was to evaluate the potential economic impacts in representative swine facilities of adopting production systems and equipment which address selected animal welfare concerns. Specific welfare concerns addressed are:

- stocking density,
- early weaning,
- gestation stalls,
- boredom and lack of environmental stimuli,
- castration, and
- access to the outdoors.

Outdoor production systems, the turnaround gestation stall, electronic sow feeders, a straw bedding system, and the sow-pig nursery have been suggested as methods to enhance space for and/or reduce the boredom of the sow herd. To respond to the early weaning concern, this study provided a sow-pig nursery alternative which permits a more efficient use of farrowing stalls but still delayed the sows entry into the breeding facility. Electronic sow feeding systems and the turnaround stall system provide alternatives to the standard gestation stall in the gestating and breeding phase of production. A straw farrowing and gestating alternative system addresses concerns about boredom and lack of stimuli. An intact boar system is analyzed to address the castration issue.

A conventional farrow-to-finish system is considered the baseline for this study. Two operation sizes, 120 and 505 sows, were considered to at least partially address economies of size related to labor use, facility investment and scheduling efficiencies.

The relative efficiency, investment and return to management and risk are compared for the baseline and alternative systems in the table on the next page for the 505 sow operation. The small operation was less profitable because of greater per unit investment and less efficient scheduling, later weaning age and labor use. Hybrid F1 replacement gilts as well as boars are purchased in the baseline and all of the alternatives except for the all-gilt, outdoor system.

<u>Pigs Weaned</u>

The number of pigs weaned per sow per year is a common measure of biological efficiency of the breeding herd. Sows in the baseline system are assumed to wean 9 pigs per litter and produce 2.29 litters per year in the small operation and 2.41 in the large one. Similar rates are assumed for the electronic sow feeder, turnaround stalls and the intact boar systems. However, the number of pigs weaned per litter is assumed to be lower for the other systems analyzed. The sow-pig nursery weans 8.5 pigs per litter because of increased mortality in the nursery. A weaned litter size of 8 was assumed for sows bedded in straw bedded pens and the southern outdoor system. The northern outdoor system is assumed to use all gilts and wean 7.5 pigs per

litter. Weaning age is also delayed in the northern outdoor and sow-pig nursery systems, resulting in reduced litters per year of 2.25 in the latter system.

Feed Efficiency

Gestation feed for the turnaround stall was increased 10 percent over the baseline to allow for increased wastage over that with a feed trough or feeder, because gestating sows must be fed on the floor. In the intact boar system, feed efficiency is better for the market boars than for the baseline barrows. However, whole-herd feed efficiency increases by a lesser amount because the market animals are sold at 210 pounds instead of the baseline to reduce boar odor. The lighter market weight reduces pork pounds sold relative to the feed required for the breeding herd.

Summary Comparison of Baseline and Alternative Systems, Large Operation

System	Pigs Weaned	Feed Efficiency	Investment	Labor Hours	Return to Management and Risk
	no./sow/year	lbs./lb.	$/sow	hours/sow/yr.	$/cwt.
Baseline	21.7	3.58	$3,320	18.01	$1.93
Electronic Sow Feeder	21.7	3.58	3,313	18.57	1.84
Turnaround Stalls	21.7	3.61	3,333	18.21	1.61
Sow-Pig Nursery	19.1	3.64	3,971	17.13	0.80
Outdoor, Southern	18.7	3.66	2,381	18.87	-0.08
Intact Boar	21.7	3.25	3,060	17.28	-2.06
Outdoor, Northern	7.5	3.79	1,750	8.77	-3.33
Straw Bedding	19.3	3.69	2,747	37.99	-3.80

Investment

A prime motivation for this study was to provide input into possible legislation at the state or federal level. Legislation requiring changes in the behavior of people or firms frequently "grandfathers in" existing operations and forces changes only when new facilities are constructed or existing ones remodelled, as in building and electrical codes. If animal welfare legislation takes this route, the appropriate baseline is the level of technology, performance, and size found in the state-of-the-art confinement systems being constructed today. Therefore, The baseline systems are environmentally controlled confinement systems with totally slatted floors in the finishing building. They were designed and priced for a climate similar to southern Minnesota. The buildings and equipment cost $3,481 and $2,770 per sow, respectively, for the 120 and 505 sow operations. Total investment with land and livestock is $4,094 and $3,320 per sow.

Total investment with turnaround gestation stalls is higher than the baseline. Total investment with gestation sow group housing and an electronic sow feeder is higher for the small operation, but lower for the large one. The system with straw bedding and solid floors requires less capital. Investment in the sow-pig nursery system is slightly less than the baseline. Intact boar system investment per sow is also reduced, due to the reduced finishing area along with some reduction in the capacity of the feed handling facilities and fewer market animals.

Labor

Labor requirements for the baseline system were set at 23 hours for the smaller size and 18 hours for the larger system, based on farm survey data. Labor per sow was increased slightly in the gestating phase for the electronic sow feeder and turnaround stall alternatives. Because the gestation facility accounts for little of the total labor in the swine operation, the increase in overall labor requirement is slight. Sow-pig nursery labor per litter is increased over the baseline, but fewer litters per sow per year reduce total hours per year.

The southern outdoor system has breeding, gestation and farrowing outside, and labor for all three stages is increased from the baseline. Nursery and grow/finish hours per pig finished are the same as in the baseline. In the northern all-gilt system, total labor hours per gilt per year are about half those for the baseline, but because far fewer pigs are produced with summer farrowing only, labor hours and cost per hundredweight are higher.

Intact boar system labor requirements are reduced because the hogs are marketed at a younger age. Straw bedding system labor requirements per sow are more than double the baseline.

Return to Management and Risk

This analysis suggests that there are good reasons for profit-maximizing swine producers to move toward confinement swine systems such as the large baseline system. This system provides a higher return than any of the alternatives considered. Returns are also positive for the large electronic sow feeder, turnaround gestation stall and sow-pig nursery systems, however. There is only a difference of $1.13 per hundredweight between the baseline and these alternatives. Small improvements in performance from those assumed here could make these systems more profitable than the baseline. Returns are negative for the large outdoor, intact boar and straw bedding systems.

The large baseline operation shows a profit of $1.93 per hundredweight. Return over feed and operating expenses was used to calculate the size of construction loan that can be serviced in an average year at a nominal interest rate. The maximum amount of the investment that can be financed out of cash flow in the average year is 38 percent for the small operation, and 62 percent for the large size.

The group housing-electronic sow feeder system increases cost per hundredweight by $0.09 for the large operation, assuming comparable sow productivity. For the large operation with the turnaround stalls, the increase is $0.32. Most of this increased cost is because of the ten percent increase in wasted feed for the sows in breeding and gestation and for the gilt pool. Costs increase by only $0.10 if feed consumption is assumed to be no more than in the baseline.

The return to management and risk for the sow-pig nursery system declines by $1.13 for the large operation, to $0.80. An increase in pigs weaned per litter from 8.5 to 9 would bring the return to management and risk to $1.98, slightly higher than the baseline. This system may have an advantage of reduced nursery mortality because the pigs are not moved at weaning. If 8.5 pigs were weaned but the four percent mortality were reduced to one percent, 0.25 more pigs would reach the grower stage and returns would be $1.55 per hundredweight.

In the southern outdoor system, return to management and risk is $-0.08 per hundredweight compared to the baseline $1.93. A 40 cents per bushel higher corn price would reduce returns to management and risk to $-2.19 per hundredweight. If the same weaned litter size could be achieved with the southern outdoor system as with the baseline, 9 pigs per litter, return would also be comparable at $2.05.

The intact boar system shows a greater loss. The impact of slaughtering costs and consumer acceptance on market boar prices are probably the least certain of any of the assumptions made in this study. A three dollar drop in the market price to $43 per hundredweight was assumed for the intact boar system, due to higher slaughtering and processing costs at a market weight of 210 pounds instead of the baseline 240. The lighter marketing weight is assumed to reduce the chance of boar odor in the meat. The combination of a lower price and fewer pounds of market animals over which to spread the cost of the breeding herd makes this system appear noncompetitive with the baseline system. Returns to management and risk for the large system, which were $1.93 per hundredweight with the baseline system, fall to $-2.06. A sensitivity analysis indicated that returns would be less than the baseline at any market weight below about 230.

The all-gilt, summer farrowing outdoor system shows a loss. The $-3.33 per hundredweight loss in the northern outdoor system ($-6.21 if feeder pigs are not purchased) illustrates why outdoor systems are no longer used by many producers in Minnesota. Traditionally, Minnesota producers farrowing outside have also used cheaper finishing facilities than the state-of-the-art one assumed here or have purchased feeder pigs to fill the facilities when their own are not available. Whether these pigs would be available under a mandated move to outdoor farrowing seems questionable. Cheaper facilities may reduce feed efficiency and increase labor requirements, however, so that the results would probably still look unfavorable. Purchasing feeder pigs is a realistic possibility for many producers in the current environment. However, if outdoor production were mandated for all or most producers in the interest of animal welfare, seasonality would most likely increase and winter-farrowed feeder pigs would not be available. Slaughter, processing and distribution costs would also likely be affected.

Return to management and risk for the large straw bedded operation declines by $5.73 per hundredweight, compared to the baseline. The declines are due mainly to a tripling in labor for the breeding herd. The sow and boar culling rate is halved to 12.5 percent per litter with this system, helping to offset the cost of higher preweaning mortality. Increasing pigs weaned to 9 per litter increases returns to management and risk to $-0.80 per hundredweight. If the system could operate with the same labor as the baseline but weaning 8 pigs per litter, the return to management and risk increases to $1.08 per hundredweight. With both 9 pigs weaned and no increase in labor, the return is $3.54 per hundredweight. At the same 25 percent culling rate as the baseline, and with eight pigs per litter and three times the baseline labor, a loss of $-4.63 results.

It is not surprising that the relative profitability of the eight systems analyzed is very sensitive to the underlying assumptions. In general, however, the analysis indicates that two of the alternative systems, electronic sow feeders and turnaround stalls, have returns to management and risk that are very similar to the baseline systems. The remaining systems analyzed have lower returns. In addition, the analysis suggests that the systems have higher returns for the larger than the smaller size. The type of analysis reported should be extended to a wider range of systems, and the detailed model presented should facilitate further work. While no effort is made here to judge the extent to which these systems enhance animal welfare, the analysis should aid meaningful economic evaluation of welfare-enhancing production systems that animal behavior research may suggest.

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1. Introduction and Purpose

Public concern about animal welfare and animal rights appears to be increasing in the United States as the 1980's draw to a close and we enter the 1990's. While the mood of the general public is difficult to gauge, one indication is a proliferation of advocacy groups dedicated to improving animal welfare and/or asserting rights of animals to be free of human intervention. Many of these groups are politically astute, well supported by donations and celebrity appearances, and are beginning to make themselves felt in the political process.

The purpose of this study is to evaluate the economic impacts that potentially could occur in representative swine facilities from adopting production systems and equipment which address selected animal welfare concerns. The advocacy groups appear to fall loosely into two categories. Proponents of "animal rights" are opposed to the exploitation of animals for any purpose. The more extreme animal rightists are strict vegetarians and feel humans should neither ride horses nor keep pets (Broom 1988). This study does not address the impacts of adopting this position, which would appear to imply drastic changes in food production and widespread dislocation of resources devoted to livestock production.

The second category advocates improved "animal welfare". Animal welfare is concerned with the animal's harmony with its environment. The welfare of an animal is defined to be its state as it attempts to cope with its environment (Broom 1988). This study is intended to provide guidance to policymakers and others evaluating the relative economic impacts of a selection of these alternative production systems and equipment.

2. Welfare Concerns and Responses Considered in This Study

The first step in this study was to select the alternative production systems and equipment to be evaluated, and conventional systems to be used as a baseline for comparison. The criteria used to select the alternative systems and equipment were:

1. The systems or equipment are the most commonly suggested in widely accessible literature from animal welfare groups, in the popular press, trade journals or academic journals.

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2. Performance data are available for the systems or equipment, preferably from controlled research trials alongside conventional systems, but anecdotal evidence from experience in commercial operations and opinions of swine production experts was also considered.

The positions of the animal welfare groups appear to be continually evolving over time. Researchers and equipment vendors are also developing new systems and equipment at a rapid rate. Hence, our list of alternative systems and equipment may soon be obsolete but appeared to be the most useful one to consider at the time we made the selections.

No attempt is made in this study to measure or evaluate the <u>welfare</u> of the animals produced using the alternatives considered. A sizable body of literature exists on the subject of how to measure animal welfare in general and the differences in swine welfare in different production systems in particular. Rather, the <u>economic impacts</u> of selected technologies which may potentially be adopted in typical swine operations are evaluated here. An attempt is also made here to describe the assumptions, sources and calculations in sufficient detail that the analysis can be extended in future research to other technologies and assumptions about productivity and costs.

The lack of a central voice in the area of farm animal welfare makes it somewhat difficult to ensure that this study considers alternative systems in keeping with current concerns. Popular press articles and literature published by the more widely known advocacy groups were used as indicators of those concerns. Scientific and popular press articles describing European and Scandinavian experience were also used as sources. European governments have begun to act individually and in concert with regard to regulating husbandry and inspection, buildings and equipment, and management practices. Those regulations provide useful insights into what might happen here. A listing of regulations and recommendations concerning animal welfare and protection in each of the major western European countries is provided in Guither and Curtis. Recommendations made by the Council of Europe's Convention for the Protection of Animals Kept for Farming Purposes in 1986 and draft regulations proposed by the Commission of the European Communities in 1988 (Sharry) were also reviewed.

2.1 <u>Stocking Density</u>

One of the most common concerns of those who espouse improved farm animal welfare and improvements in many of those practices surrounding intensive animal agriculture is stocking density and space requirements for the individual animal. The sow, which spends an extended time span on the farm and is often subjected to individual confinement, becomes a major beneficiary of such concern. The outdoor systems, the "turnaround" stall, electronic sow feeders, the straw bedding system, and the sow-pig nursery all provide different amounts of space to the breeding herd at different stages of production.

2.2 <u>Early Weaning</u>

Early weaning has been listed as a major concern in Europe (as well as the United States and Canada). Later weaning is commonly considered to delay estrus and breedback of the sow. Delayed breedback reduces pigs produced per sow per year, lowering overall feed and labor efficiency because fewer pounds of pork are produced to cover feed and labor for the breeding herd. If the sow remains in the farrowing room until weaning, the delay also reduces the number of pigs that can be produced per farrowing stall and increases per unit capital costs as well as fewer pounds of pork are produced per stall. To respond to this concern, this study provided a sow pig nursery alternative which made for a more efficient use of farrowing stalls but still delayed the sows entry into the breeding facility.

Another alternative that is not considered in detail in this study is lactational estrous (breeding the sow before weaning to increase litters per year without early weaning). Rowlinson et al. reported on sows and litters housed in groups with ad lib feeding and the ability of sows to separate from suckling piglets and interact with boars. In this study 78 percent of the sows experienced estrus at an average of 31.6 days post partum. Those that did not display lactational estrus were in heat within five days post weaning. It should be noted that in this study, piglet performance was monitored. At 40 days of age, piglets in the test litters averaged 3.5 pounds less than those in the control portion of the study.

In Sweden, an enterprising manager has developed a custom farrowing pen that protects piglets and prevents their departing the stall while allowing the sow to depart (Bell, Halverson). It is stated that this welfare oriented system exceeds Sweden's strict animal welfare regulations while actually improving production when compared to more conventional systems (Halverson).

It is the opinion of many animal scientists that complete litter separation is necessary in order for the onset of estrus to occur (Jerry Hawton, personal communication). Newton et al. reported that of 140 sows observed for lactational estrus, only nine were observed in heat. This was with periods of six hour litter separation and boar contact. It would appear that any success with such a system would involve boar contact (Walton).

Lactational estrus may become a topic of increasing interest if regulations or recommendations occur that restrict or question the use of early weaning or hot nurseries. Currently, results of lactational estrus studies are conflicting as is the opinion of many animal scientists. The Swedish producer mentioned above appears to be the only one using this system successfully on a commercial basis at this time, and even he appears to have some difficulty making it work in the summer (Halverson). Conception rates in this system appear to be highly correlated to seasons of the year with the optimum days to conception postpartum being 35.4 (Bell). Thus, some success has been reported by one Swedish producer, but more information on the managerial inputs required to make these systems produce consistent litter performance is needed to make meaningful comparisons.

2.3 Gestation Stalls

Another welfare concern that can be judged as major both intuitively and through the European experience is the gestation stall. Any such device that limits freedom of movement (Sainsbury) over a long period of time might be considered a welfare concern. Electronic sow feeding systems and the turnaround stall system provide alternatives to the standard total confinement stall in the gestating and breeding phase of production.

2.4 Boredom and Lack of Environmental Stimuli

The lack of straw in today's more intensive swine raising systems is a concern that is reflected in much of the European and Scandinavian recommendations and regulations. A straw farrowing and gestating alternative system addresses this concern.

2.5 Castration

The practice of castration has been described by some in the European Community as a useless mutilation. An intact boar system is analyzed to address this issue.

2.6 Access to the Outdoors

Lastly, the use of extensive, outdoor production is gaining acceptance in much of Europe and to a lesser extent, gaining acceptance in the southern United States. As outdoor production is regional in its application in the United States, a more limited analysis is provided of this alternative because of climatic limitations.

2.7 Alternative Systems Considered

The major alternative systems considered then were:

1. Extensive/outdoor breeding, gestation, farrowing and nursery,
2. The turnaround stall as a potential improvement on the conventional gestation stall,
3. Electronic sow feeders for use in group housing of gestating sows,
4. The sow-pig nursery, with farrowing in conventional farrowing stalls followed by movement to two-litter nursery pens at about one week of age,
5. A straw system with farrowing, breeding and gestation in a straw bedded, solid manure facility, and
6. An intact boar system, where boars are not castrated but are marketed at lighter weights to avoid boar odor.

2.8 Organization of the Analysis

The rest of the paper is organized as follows. First, the baseline conventional system is described. Physical performance data, space requirements, building and equipment descriptions, investment requirements, labor requirements, and costs and returns for an average year of operation are presented in tables and discussed. Then, each alternative system is discussed with emphasis on the differences between it and the baseline system. Two operation sizes were considered to at least partially address economies of size related to increasing size of buildings and manure storage area, volume and perimeter relationships.

The main business factors considered for each system are as follows. The outdoor and straw system analyses key in on investment and sow productivity, with consideration of feed and labor differences. The turnaround stall makes slightly better use of space because some alley space in the building can be eliminated. The electronic sow feeder appears to increase labor slightly because of the increased difficulty of handling sows who are running loose in groups instead of being confined. The lump sum investment in the computer and related equipment also appears to penalize the small operation compared to the large one with the electronic sow feeder system. The sow-pig nursery reduces sow productivity because of delayed rebreeding and increased mortality, partially offset by reduced investment. In the intact boar system, differences in hog prices and feed efficiency are the main factors considered.

3. Baseline Production System

The choice of baseline conventional swine production systems and equipment is as difficult as the choice of alternative ones, because a wide variety of systems constructed over an extended period of time are currently in use. A prime motivation for this study was to provide input into possible legislation at the state or federal level. Legislation requiring changes in the behavior of people or firms frequently "grandfathers in" existing operations and forces changes only when new facilities are constructed or existing ones remodelled, as in building and electrical codes. If animal welfare legislation were to take this route, which seems likely, then the appropriate baseline is the level of technology, performance, and size, found in the state-of-the-art confinement systems being constructed today. That is, the new systems being built at the current time are the ones that will be affected by the legislation. Existing systems will only be influenced as they are replaced. Alternatively, a less likely direction for legislation to take would be to force changes in existing swine facilities which were constructed years ago and which are typically smaller and utilize different technologies than those being installed today. This study describes a state-of-the-art production system as the primary baseline, in line with the more likely legislative scenario.

Climatic conditions are a major factor in the choice of a swine production system. Proximity to supplies of feed and other inputs and to markets, distance from population centers which might be affected by odors, and environmental and zoning regulations will also affect choice of a system and resulting performance and profitability. Assumptions about these factors were geared to southern Minnesota conditions. The results should also apply well to the rest of the Upper Midwest region of the United States. They will apply less well to regions with milder climates.

3.1 Profitability and Economies of Size

Farm record summary programs around the U.S. generally indicate that swine operations vary widely in production and economic performance, as do all types of farms (see, e.g., Olson et al.). Defining a set of parameters to describe a farm situation representing such a range of performance is a challenging task.

The logic used in defining the baseline system performance was as follows. New, relatively large facilities are being constructed today, as the popular press articles cited below indicate. The fact that this construction is taking place indicates that operators of such facilities are projecting returns to the fixed resources of labor, management and capital that are at least competitive with alternative opportunities. This construction appears to have continued at a fairly steady rate for a number of years, based on the surveys by James Rhodes and associates, implying that profitability is in fact being achieved (Rhodes). It would appear then that our large baseline system representing such operations should indicate a favorable level of profitability.

On the other hand, conversations with county extension staff around Minnesota indicate that few smaller facilities are under construction today, implying a less favorable profitability situation for them. Rhodes also found in his 1989 national survey that smaller operations were less frequently planning expansion than were larger ones. We thus expected that the smaller baseline system would show long run profitability that was negative or at least below alternative opportunities. Of course, it is possible that labor and capital resource limitations and non-economic factors may prevent such ventures from moving forward even if marginally favorable profitability is projected. However, it seems likely that if profit projections appeared favorable enough, ways would be found to overcome these other constraints. The absence of this construction activity suggests that producers currently project marginal or negative profits for the smaller facility.

3.2 Discussion of New Swine Housing Technologies

Over the past several years there has been a resurgence of interest in swine housing alternatives for the upper Midwest. This interest has been spurred in part by an Iowa State study showing that the average cost of producing pork on Iowa Swine Enterprise Record Program farms in the mid-1980's was higher than in intensively managed operations on the fringes of the Corn Belt, in part because of less efficient facilities (Kliebenstein et al.). This study has been followed by a number of popular press articles about producers and builders who are constructing buildings which use innovative designs and cut corners to reduce costs. Little actual building seems to be underway in Minnesota, making information on current costs of newly constructed buildings fairly scarce. However, recent articles in trade magazines have discussed the characteristics and costs of new facilities being constructed in other midwestern states.

Most of the recent articles have concerned finishing building design. It appears that preferred features for finishing buildings under Minnesota climatic conditions include:

- totally slatted floors
- central, outside earth storage basin for wastes
- scrapers or a pull-plug under the slats to move wastes to the central storage
- solid, insulated walls with total environmental control[1]

The 1989 Agricultural Building Cost Manual published by the Boeckh unit of American Appraisal Associates for use by farm appraisers gives detailed cost estimates by building component which can be used to combine components

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[1] The June, 1990 issue of Hog Farm Management reported costs for a finishing building in Drexel, Missouri as well as comments from a Murphy Farms representative on features they would recommend for adapting their designs to Iowa. Murphy Farms, with operations mainly in North Carolina, is believed to be the largest swine producer in the U.S., with 600,000 head marketed per year (Iowa Farm Bureau). The April, 1989 issue of the same magazine also lists features and costs for buildings in Oakville, Washington and Nevada, Iowa, along with recommendations from Land O'Lakes, Hog Slat representatives and a veterinarian from Fairmont, Minnesota. The individuals quoted in these articles seem to prefer totally slatted floors for finishing barns to prevent problems with pigs dunging on the solid portions of partially slatted floors. The March issue of Pork '90, on the other hand, describes use of outside wall air inlets to control dunging patterns on partial slats. The same issue describes "maze finishing" to reduce cleanup time and increase capacity of finishing barns on an all-in/all-out system. The September 15, 1990 issue of the National Hog Farmer also describes a partially slatted finishing barn in Ontario with an innovative ventilation system to improve pig comfort and prevent dunging problems.

Poor interior air quality in swine confinement buildings is becoming a major human health concern and contributes to the difficulty of finding and keeping employees. Scrapers are common in Minnesota, but are considered to cause greater air quality problems for workers and animals in the building because of ammonia buildup compared to some other manure removal methods. The ammonia is released as the manure-soaked floor dries after the scraper passes.

Pit recharge systems are currently being recommended as an alternative to scrapers to improve air quality (Connor). With the pit recharge system, a pit under the building is emptied every 7-10 days, before gas-generating microbial action reaches peak levels. The pit is then refilled with about 12 inches of liquid to cover the manure falling into the pit and prevent the drying floor surfaces which generate ammonia with the scraper system. The liquid comes from the second stage of a lagoon, so that a lagoon is required rather than an earthen storage basin.

Some poorly designed lagoons were constructed in the late 1970's and early 1980's. Odor and leakage problems caused a trend in the direction of earthen storage and away from lagoons. Today, state standards for lagoon construction in Minnesota are strict, in part because of the earlier problems (Jacobson, personal communication). Today, some Minnesota producers feel that it would be more difficult to obtain local approval to construct lagoons than storage basins. Others are making lagoons work in Minnesota, however, when sized and designed properly (Christensen).

into a cost estimate for a complete building and look at the impact of varying the cost of any one component on the total. Boeckh does not include information on all of the latest innovations in components. For example, it doesn't mention curtain-sided walls, which appear to be gaining in popularity for finishing buildings and perhaps for gestation buildings as well. A number of vendors of equipment and building components were contacted at the June 1990 Pork Expo in Des Moines, Iowa for additional details which were used to adjust the Boeckh information.

Unpublished estimates by Professor Doug Overholtz, Kentucky extension engineer were also considered. These 1988 cost estimates were adjusted for inflation using the index of prices paid by farmers for building and fencing materials from USDA's Ag Prices. The index rose 3.6 percent from the 1988 annual average to the July, 1990 level. The rise from July 1989 to July 1990 was 1.4 percent. This increase is small relative to the other uncertainties in these figures, and any inflation in the 1988 costs has been ignored.

The Boeckh manual includes multipliers to adjust building replacement costs by zip code areas within states for differences in building costs. These multipliers indicate costs in rural areas of Minnesota are about 6 percent higher than western Kentucky, 11 percent higher than western or eastern Iowa, 16 percent higher than Missouri, and 42 percent higher than North Carolina[2]. Boeckh has just a few broad construction categories, making it unclear how much of the locational difference is due to heavier insulation and snow loads compared to prices and state policy regarding such things as taxes.

Boeckh's cost for insulation was included in this study. Earth berms were not explicitly considered. Boeckh's estimates for buildings with solid walls were the main focus of the analysis, but these estimates were then reduced by four percent for the growing/finishing buildings to allow for the lower cost of curtain-sided walls based on the price relationships cited in the press. A cost was included for fans, but not tubes, in all of the buildings except for the growing/finishing buildings, which were assumed to be naturally ventilated. Heaters were included for farrowing and nursery buildings but not gestation or finishing.

Care must be taken to adjust for local labor costs when secondary sources of building costs are used. Some buildings described in recent articles appear to have been constructed largely by unpaid operator labor or by local workers hired at low wage rates, while others are turnkey facilities constructed by contractors hiring skilled crews. Home built swine facilities are estimated to cost about 55 percent of the turnkey cost, except for a gestation building with stalls which is 67 percent of the turnkey cost because more of the cost is in equipment which is usually purchased regardless of whether the operator or a contractor builds the building (Overholtz). Another

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[2] The Murphy Farms representative quoted in the June, 1990 Hog Farm Management issue estimated Iowa finishing barns cost 33 percent more than those in North Carolina. The Boeckh multipliers indicate Iowa estimates are 27 percent greater than North Carolina. Differences in assumptions about building features could easily explain the difference between these two figures.

estimate of the difference between turnkey and home-built costs is printed in an article in the June, 1990 issue of Hog Farm Management. A contractor representative estimates that contracting margins and labor costs increase the cost of a finishing barn from $80 if home built to $125 on a turnkey basis. This home-built cost is then 64 percent of the turnkey cost.

3.3 PIGPLAN Use for Facility Sizing and Scheduling

The building and equipment sizes were determined using the PIGPLAN computer spreadsheet template for Supercalc 4 developed by Professor Howard Person of the Department of Agricultural Engineering, Michigan State University (Person). This computer program operationalizes guidelines published in the Swine Housing and Equipment Handbook published by the Midwest Plan Service. PIGPLAN allows the user to specify a large number of variables such as number of farrowing groups per year, age at weaning and age to market weight, and then make adjustments to compare different numbers and sizes of buildings to approach a minimum cost design. PIGPLAN appears to be a useful tool to evaluate changes which change these variables. It focuses on selecting a number of farrowing rooms and stalls per room to allow the user to select those which project the number of pigs produced per year and idle time at each stage of production. The user can try different designs and compare the results in an iterative fashion. PIGPLAN simulates operation of a particular design but does not optimize. The degree to which users can approach a design which maximizes profitability depends on how much effort they devote to comparing the difference in investment and operating and ownership costs for each alternative.

3.4 Baseline System Performance

The two main data sources available for use in defining the performance of the baseline system were the PigCHAMP database summarized by the University of Minnesota School of Veterinary Medicine, and the Southwestern Minnesota Farm Business Management Association (FBMA) swine enterprise record database summarized by the Department of Agricultural and Applied Economics (Wilkins, Olson et al.). PigCHAMP contains breeding, farrowing and weaning performance of the breeding herd as well as a limited amount of growth and feed cost data for finishing swine. The FBMA data includes a breakdown of feed and other cash operating and overhead expenses, along with sales and inventory changes. The FBMA swine operations are somewhat larger than average for Minnesota and the U.S., but are smaller and less intensively managed than the PigCHAMP operations. The FBMA operations are also smaller and less intensively managed than the baseline system in this study. The most recent PigCHAMP breeding herd summary available was for 450 farms in the 1988 calendar year. The latest FBMA data available was for 1989, with 51 farrow-to-finish enterprises, 11 feeder pig production enterprises and 30 finishing enterprises. The PigCHAMP breeding herd data was summarized by herd size, with groupings of 0-175, 176-475 and over 475 sows. The FBMA farrow-to-finish operations averaged 202 litters and 1.85 litters per sow in 1989, which works out to be about 110 sows. Pigs weaned averaged 8.42 per litter, and about 15.6 per sow per year. The PigCHAMP farms averaged 251 sows in 1988, with 19.5 pigs weaned per mated female per year. Part of the difference in weaning performance between PigCHAMP and FBMA farms may be due to the way sows are counted in the different systems (at what age gilts are included), but there still appears to be a marked difference in size and management intensity between the two groups of farms.

Another data source is an Iowa State University task force report that includes data from the Iowa State University Swine Enterprise Record Program, as well as data from a limited sample of intensively managed swine operations on the fringes of the Corn Belt (Kliebenstein et al).

The breeding herd performance of the baseline system was based largely on the PigCHAMP data (Table 3.1). It is recognized these performance levels are above industry averages, but they were selected as representative of performance in a well-designed, state-of-the-art facility. Whole-herd feed efficiency is set at roughly 3.6 pounds of feed per pound of pork, which is the average for the top ten percent of the Iowa record farms in 1986 but greater than the 3.4 reported by Kliebenstein et al. (1988) for the intensively managed operations. This is also better than the 3.91 average for the FBMA farms. Pigs weaned per litter was set to 9.0, slightly above the PigCHAMP average of 8.6 because of the assumed purchase of more prolific terminal F1 gilts. Feed efficiency figures are calculated based on pounds of market hogs and cull sows and boars sold minus gilts and boars purchased. The purchased gilts are assumed to weigh 220 pounds and the boars, 250 pounds. The 25 percent cull rate is assumed to be total sows removed from the herd, with the death loss subtracted to arrive at the number of cull sows sold.

The baseline systems were designed to reflect the more significant and easily quantified economies of size evident at two operation sizes, but resources available for this study were not sufficient to do a complete economies of size analysis. The main economies of size reflected in this study are differences in building construction costs per unit of space, and the differences in breeding herd performance shown in the PigCHAMP summary. PIGPLAN, used for scheduling and sizing the facilities, recognizes such factors as cleanup time and time intervals required for a group of sows to farrow. The increased number of farrowing and other rooms in the large system improves scheduling efficiency and litters per sow per year, and is another source of improved profitability with the large size. A major factor not considered here is volume purchasing and marketing premiums. The same prices for feed and pork were used for both sizes.

The process of sizing the facilities began by first deciding on approximate sizes of 100-200 sows and roughly 500 sows for the "small" and "large" systems, and then selecting a number of farrowing rooms and stalls per room that would accommodate a breeding herd in each of those size ranges under schedules calculated by PIGPLAN. The PigCHAMP summaries for 0-175 and over 476 sows were used as the source of the weaning age (28 days for the small and 24 days for the large operation), rebreeding days, and pigs weaned per litter. A 80 percent conception rate and a target of 4 days idle for cleanup were assumed. In reality, weekly scheduling may be easier with a 21 or 28 day target weaning age than with the 24 days assumed here for the large operation, but the 24 day age better reflects the four day difference between large and small and implied economies of size reflected in the PigCHAMP data. The Swine Housing and Equipment Handbook was used as a guide to number of farrowing rooms and stalls per room, with the final choice being somewhat arbitrary. Generally, idle facility time is reduced as the number of rooms increases, but construction costs for the extra room dividers and equipment would also likely increase. Average age of pigs reaching market weight of 183 days was taken from the "Exceptional" growth curve in Figure 1, page 7 of the handbook. The minimum age to market of 24 PigCHAMP farms was 179 days, with an average age of 208. A market weight of 241 pounds was assumed, compared to an average of 232 for the PigCHAMP farms. The seven-market average market weight for barrows and gilts was 246 pounds in February, 1991. Farrowing facilities with 32 and 120 stalls were selected for herd sizes of 120 and 505 sows, respectively.

The calculated capacity and breeding herd performance of the systems is shown in the bottom panel of Table 3.1. Pigs weaned per mated female per year of 20.6 for the small size is a bit higher than the 19.6 average for the smaller PigCHAMP farms. The large farm 21.7 is a bit higher than the PigCHAMP 19.9 for the larger farms. The scheduling pattern for the small farm includes six days for cleanup of the farrowing and nursery rooms instead of the four days entered as a target. One reason why litters and pigs weaned per sow shown here are higher than the PigCHAMP averages is that the PIGPLAN calculations do not allow for occasional disruptions in the schedule due to disease outbreaks and other factors that disrupt scheduling on the farms in PigCHAMP.

The feeding program was described by stage of production in order to evaluate the impact of alternative systems which change scheduling and growth rates on whole-herd feed efficiency (Table 3.2). The breeding herd rations and daily quantities fed were taken from Pork Industry Handbook fact sheet PIH-23, "Swine Rations". The market animals' average daily gains and feed per pound of gain at different stages were taken from charts on page 7 of "Life Cycle Swine Nutrition" (Holden et al.). Feed per pound of gain for the small baseline operation was then adjusted proportionally across all stages to arrive at a whole herd feed efficiency of 3.6. The proportions of corn and supplement in the rations at each stage are also shown for the market animals. The breeding animals received a ration of 82 percent corn and 18 percent supplement throughout.

For the large baseline operation, it was assumed that the pigs would weigh 12 pounds at the 24 day weaning age compared to 15.5 pounds for the small operation's 28 day weaning age. Nursery feed would increase by 6.3 pounds per pig or 57 pounds per litter to compensate for the lighter starting weight. The sow would require 39 pounds less lactation feed because of the four day earlier weaning and would lose 10 fewer pounds of body weight during lactation, however, saving 35 pounds of gestation feed to replace this lost weight. It was assumed that it takes less nursery feed to feed the pigs directly than to feed the sow, so that whole-herd feed efficiency improves slightly to 3.58. The later weaning, as well as an extra day before rebreeding shown in the PigCHAMP summary, results in fewer litters per mated female per year in the smaller operation, 2.29 compared to 2.41, which also acts to reduce whole-herd feed efficiency slightly because the breeding herd's feed is spread over fewer litters.

Table 3.1. Facility Scheduling and Sizing Parameters and Resulting Size and Efficiency Estimates, Baseline Systems

	Small	Both	Large
<u>Input Parameters</u>			
Average Age of Pigs at Weaning	28		24
Number of Days to be Used for Rebreeding	9		8
Target Days Farrowing and Nursery Rooms Idle for Cleaning and Repair	-	4	-
Number of Pigs Weaned Per Litter	-	9.0	-
Number of Farrowing Rooms	2		6
Farrowing Stalls Per Room	16		20
Conception Rate Expected	-	80%	-
Average Age of Pigs at Market Weight	-	183	-
Post-weaning death loss			
Nursery	-	4.0%	-
Grow/finish	-	1.9%	-
Total	-	5.9%	-
Breeding herd death loss per year	5.1%		6.2%
Sow culling rate per litter	-	25%	-
<u>Results</u>			
Pigs Weaned Per Year	2,477		10,950
Number of Sows in the Herd (not including gilts past market weight but not yet bred)	120		505
Litters Per Year	275		1,217
Litters Per Mated Female Per Year	2.29		2.41
Pigs Weaned Per Mated Female Per Year	20.6		21.7
Actual Days Farrowing and Nursery Rooms Idle for Cleaning and Repair	6		4

Table 3.2. Growth and Feeding Performance, Small Baseline System

	Stage		
Market Animals	Nursery	Growing	Finishing
Pigs/Litter	8.64	8.56	8.46
Ending Weight	56	121	241
Gain, Lbs. Per Pig	41	65	120
Ending Age	74	115	183
Days in Stage	46	41	68
Average Daily Gain	0.89	1.58	1.76
Feed Consumed Per Animal, Lbs.	76	188	479
Feed Lbs. Per Lb. Gain	1.85	2.9	4.0
Corn Percent in Ration	69.75	77.90	83.30
Supplement Percent in Ration	30.25	22.10	16.70

	Breeding				Gilt
Breeding Herd	Sow/Gilt	Boar	Gestation	Lactation	Pool
Period Considered	Litter	Year	Litter	Litter	Repl.
Total Days In Period	15	365	117	31	30
Lbs. Gain Per Animal	10	0	75	-	-
Feed Lbs. Per Day	5.2	7	5.20	13	5.20
Total Feed/Animal	78	2,555	608	403	156

Calculated whole-herd feed efficiency,
feed pounds per pound of pork 3.60

3.5 Facility Sizing

The space requirements per pig assumed for the baseline system are shown by stage of production in Table 3.3. It should be noted that the 40 square feet stated as provided for the farrowing sow is not all available to the sow as only one half of the five foot width is actually under the sow, the remaining 2.5 feet being creep area. For the gestating sow, 16 square feet is assumed, including alleys. The summary of design data in the Swine Housing and Equipment Handbook (MWPS-8) lists gestation stall sizes under space requirements as 1'10" X 6' for the 250-300 pound gilt and 2' X 7' for the 300-500 pound sow. These stalls provide 11 and 14 square feet respectively to the confined sow.

Curtis et al. provide a table of stall dimension requirements for sows at differing weights. By using the Curtis figures, it is estimated that a 330 pound sow needs slightly in excess of 15 square feet of stall space, a 440 pound sow needs nearly 18 square feet, while a 550 pound sow would require approximately 20.4 square feet and a 660 pound sow needs nearly 23 square feet of space. Curtis et al. judge this space to be appropriate for sternal resting or lying partially recumbent and to rise or lie down without restriction. Full recumbency or turning around could not be accomplished within these space limits. Thus, their figures suggest that many gestation stalls and some farrowing stalls in the United States fail to provided adequate space to fulfill physical and behavioral needs. Nonetheless, the 16 square feet per gestating sow, which implies stalls of about 2′ x 7′ or less, is assumed because it is recommended in MWPS-8 and appears to be common practice.

The facility sizing process began by selecting a number of farrowing stalls per room and a number of farrowing rooms for the small and large operations are typical of designs currently recommended by agricultural engineers. These and the other parameters from Table 3.1 were entered into the PIGPLAN program to arrive at the numbers of bred sows and gilts in inventory, 120 for the small operation and 505 for the large one, and the capacities required for the facilities at each stage of production (Table 3.3).

PIGPLAN assumes that nonbreeding sows are kept in the breeding building for 30 days and then culled. This results in a smaller required breeding and gestation capacity than provided in the Swine Housing and Equipment Handbook for weekly farrowing, 405 compared to 639 with 120 farrowing stalls. The difference is apparently due to an assumption of a less stringent culling strategy in the handbook. The PigCHAMP data shows a 90 percent conception rate, so 80 percent is fairly conservative. Using 90 percent in PIGPLAN would reduce breeding and gestation capacity further to 390, but because 405 (at 80 percent) is already so far below the handbook recommendation, it was not lowered further by increasing conception to 90.

Table 3.3. Space Requirements, Baseline System

	Maximum Pig Weight	Pen Area Per Pig	Building Area Per Pig	Capacity Required Small	Capacity Required Large
	lbs.	sq. ft.	sq. ft.	head	head
Farrowing	450	40	64	32	120
Breeding					
Boars	450	40	90	9	25
Sows	450	30	22	40	125
Gestation	450	16	22	64	280
Gilt Pool	450	16	22	34	42
Nursery	75	3.5	5.25	495	1,854
Grower	140	6	6.5	275	1,204
Finisher	241	8	8.7	413	2,064

Source: Pen area per pig from Person, except for farrowing which is based on a 5′ x 8′ farrowing stall. Building area per pig includes space for alleys and breeding pens based on building designs in the Swine Housing and Equipment Handbook and Levis.

3.6 Baseline System Investment

Facility costs were calculated using Boeckh, quotes from venders and turnkey construction contractors, and the assistance of state and national extension specialists. All building shells were calculated on a square foot basis using cost estimates per square foot from Boeckh, with adjustments for such options as insulation, floor type, heating and cooling, economies with regard to overall dimensions and location multipliers by zip code. The building shells are assumed to be of average construction quality except for the growing/finishing facility which is assumed to be of economy quality and reduced 20 percent in cost from the Boeckh baseline. The baseline system was designed using southwestern Minnesota as the location. Equipment was added with costs as outlined in Table 3.4.

Manure storage is liquid with no straw and is calculated for each stage of production using PIGPLAN as a guide for manure storage required for semi-annual pumping. A base charge per gallon was charged to cover a central earth storage pit and piping to move the manure from each building to it, from Boeckh. The per gallon cost was varied depending on the pit size, from $0.139 for the small operation to $0.096 for the large operation. The total manure storage cost is $320 and $230 per sow for the small and large operations, respectively. In practice, manure storage and handling costs will vary widely depending on the environmental sensitivity and regulations at a given site. Increased public awareness of agricultural pollution will probably increase manure storage and handling costs in the future.

Land occupied by the buildings and manure storage only is included, 2.5 acres for the small operation and 5.7 acres for the large one. Additional land is needed for manure disposal, but likely will produce crops whose value covers the cost of owning the land.

When assessing the accuracy of the facility costs, one should remember that these are considered turnkey facilities that are ready to go into immediate production. This includes all penning, feed storage and delivery, ventilation equipment, and water (excluding well). The facilities would be considered state-of-the-art, designed for total confinement and environmental control.

The total investment requirements for the baseline systems are shown in Table 3.5. The buildings and equipment cost $3,481 and $2,770 per sow, respectively, for the small and large systems, calculated using the prices shown in Table 3.4. Total investment with land and livestock is $4,090 and $3,320 per sow.

3.7 Baseline System Labor Requirements

Labor requirements per sow are shown in Table 3.6. Pork Industry Handbook fact sheet PIH-48, "Pork Production Systems with Business Analyses - Selecting the Right System", revised in 1984, includes estimates for high investment confinement systems of 22 hours of time directly involved in swine production, and 28 hours of total labor including time for planning, keeping records and attending to other overhead items that are part of running a farm business. Anecdotal evidence suggests that these PIH figures may be about right to somewhat high. The handbook does not provide any information on how labor use varies with size, so survey data from 34 FBMA farms were used as estimates of 23 hours for the smaller size and 18 hours for the larger system (Lazarus, page 7). The reasonableness of these estimates is partially confirmed by anecdotal evidence that actual operations near the large size usually employ three or more persons while small operations in the 80 to 120 sow size range are usually one man operations with some extra family labor.

These totals were allocated to stages in order to evaluate the impact of changes in individual stages on the total labor requirement. Labor requirements for the alternative systems were estimated by adjusting the numbers in Table 3.6 proportionally to changes in animals and days in each stage.

Table 3.4. Prices Used for Investment Calculations, Baseline System

		Stage				
Item	Units	Far-rowing	Nur-sery	Growing/ Finishing	Gesta-tion	Breed-ing
Capacity measured in units:		stall	pig	hog	sow or gilt	sow or boar
Building						
Shell:						
small	foot^2	\$20.93	\$10.88	\$15.34	\$17.06	\$18.75
	head	1,340	57.11	119.99	375	646
large	foot^2	17.83	8.68	13.24	13.62	15.16
	head	1,141	45.58	104.48	300	505
Equipment, per head, both sizes						
Stalls and pens[a]		260	49.22	16.15	100	200
Feed system[b]		40	13.80	12.69	60	46
Water		20	3.40	2.80	20	20
Fans[c]		44	3.71	0.00	11	22
Total Equipment		364	70.13	32.40	191	288

[a]Breeding stall cost figures include individual boar and sow stalls with breeding pens factored in.

[b]Feed is delivered to the farrowing facility by auger from an outside bin. Sows in the farrowing facility are hand fed using a cart. No provision is included in the farrowing facility for creep feeding. Flex augers deliver to feed bowls (for sows and boars) and ad lib feeders (for the nursery and growing/finishing pigs). The initial cost of these systems assume \$1,000 to \$1,500 per 150 feet of tubing (including the drive head) and \$6 per drop. The cost of feeders is based on vendor prices and Boeckh. Steel outside feed storage tanks are assumed to be of sufficient size to hold the feed consumed over a 30 day period. The initial cost of storage tanks is based on Boeckh.

[c]Ventilation requirements (cubic feet per minute or cfm) were based on the Swine Facility and Equipment Handbook.

Table 3.5. Investment Requirement for the Baseline System

	Buildings	Equipment	Total	Per Pig Place
Small				
Land, 2.5 Acres @ $1,000			$2,500	
Facilities:				
Farrowing	$42,865	$11,648	$54,513	$1,704
Nursery	28,259	34,714	62,985	127
Growing/Finishing	83,193	22,291	104,843	152
Breeding	31,679	14,112	45,791	935
Gestation	36,778	18,718	55,496	566
Manure Storage	38,351	0	38,351	320
Feed Mill and Grain Storage	19,503	18,500	38,003	
Miscellaneous Equipment	0	17,785	17,785	
Total Facilities	$279,998	$137,769	$417,767	
Per Sow	$2,333	$1,148	$3,481	
Livestock:				
Sows (120 head @ $250)			$30,000	
Gilt Pool (34 @ $250)			8,500	
Boars (9 @ 600)			5,400	
Market Animals (683 @ 39)			26,608	
Total Livestock (846)			$70,508	
Total Investment			$490,775	
Per Sow				$4,090
Large				
Land, 5.7 Acres @ $1,000			$5,700	
Facilities:				
Farrowing	$136,931	$43,680	$180,611	$1,505
Nursery	84,504	130,021	214,525	116
Growing/Finishing	341,442	105,883	447,325	137
Breeding	75,795	43,200	118,995	793
Gestation	96,452	61,502	157,954	490
Manure Storage	116,250	0	116,250	230
Feed Mill and Grain Storage	85,717	55,000	140,717	
Miscellaneous Equipment	0	22,511	22,511	
Total Facilities	$937,092	$461,797	$1,398,889	
Per Sow	$1,856	$914	$2,770	
Livestock:				
Sows (505 head @ $250)			$126,250	
Gilt Pool (42 @ 250)			10,500	
Boars (25 @ 600)			15,000	
Market Animals (3,078 @ 39)			120,044	
Total Livestock (3,544)			$271,794	
Total Investment			$1,676,382	
Per Sow				$3,320

Labor was allocated to each stage of production in a somewhat arbitrary manner. Kliebenstein et al. (1980), in a 1980 study at Missouri, estimated 24 hours per sow for a farrow to finish operation and 18 hours per sow for a feeder pig operation. This indicates that seventy five percent of labor goes into the breeding herd and the production of 40 pound feeder pigs. The remaining 25 percent is divided so that 20 percent goes to growing/finishing in a farrow to finish operation with the remaining 5 percent going toward the final 15 to 20 lbs of growth in the nursery.

Labor in the farrowing house is considered to make up the largest percentage of the total as observation of the sow and litter is crucial to pigs weaned. In addition, this is the stage where tail docking, tooth clipping, iron shots and castration occur. It is also a common practice to hand feed the sow in the farrowing barn which further adds to the labor requirements in comparison to other stages where semi-automated feeding systems can be used. For these reasons, 40 percent of the total labor is reported to go to farrowing.

Labor in the nursery was calculated at 20 percent of the total. This takes into account the added management required to observe and husband pigs that are weaned prior to 28 days. Consideration is given to ensuring that pigs make the transition from sow's milk to dry feed and any medication that might be injected during this vital stage. One would assume that cleanup for this stage of production in an all in all out system would be quite stringent.

Labor in the breeding barn comprises 15 percent of the total. This takes into account estrus detection and movement of sows and boars from individual stalls to the breeding pen. Configuration of the breeding barn is a major factor affecting the amount of labor required. We assume in this system that movement from stall to breeding pen and back is done with relative ease.

The gestation stage in this individual stall, automated precision feeding system, would seem to require little labor. Other than a daily walk through, sow movement, and cleanup, little is provided as the manager establishes his labor priorities. For this reason, only 5 percent of the total labor required was assessed to the gestation phase. Manure handling and application, while part of the total of 18 and 23 hours per sow, was not a major consideration in the stage by stage breakdown.

Table 3.6. Annual Labor Requirements by Stage and Size for the Baseline System

	Small	Large
	hours per sow per year	
Stage		
Farrowing	9.18	7.20
Nursery	4.59	3.60
Growing-Finishing	4.59	3.60
Breeding	3.44	2.70
Gestation	1.15	0.90
Total	22.96	18.00

3.8 Baseline System Economic Costs and Returns

Costs and returns per litter, per hundredweight and for the total operation are shown in Tables 3.7 and 3.8 for the small and large systems, respectively. The slight difference in cull sow sales between the sizes is due to the higher sow death loss in the large operation. The difference in boar sales is due to the more efficient use of boars in the large operation. The largest cost difference between the sizes is in ownership costs, with the large size costing $2.16 less per hundredweight than the small one. Feed costs account for 48 and 52 percent of the totals for the small and large sizes, respectively, while ownership costs are the next largest cost items at 19 and 16 percent.

The operating costs include a marketing cost of $1.50 per head or $13.50 per litter, based on one-half of the per head purchasing and marketing charges in Fales' hog finishing budgets. The cost of replacement boars and gilts cost assumes a 25 percent culling rate per litter. Veterinary, utilities, repairs, and supplies are averages from the southwestern Minnesota FBMA farms, rounded off with five percent added for inflation (Olson et al.). Fire and wind insurance on buildings and livestock, and property taxes on buildings, equipment and land are based on typical southern Minnesota rates and the investment values shown in Table 3.5. Interest on operating costs was charged at 11 percent. Marketing, veterinary, utilities, repairs, supplies and interest on operating capital are assumed to be the same per litter for both sizes, so are combined under "other" for the large operation.

Economic profitability was the main criterion used to evaluate the baseline system and compare the alternatives in this analysis. Cash flow concerns were also recognized by calculating the level of indebtedness that can be financed from net cash flow in an average year, as a percentage of total investment.

Profitability was measured in 1991 dollars. All inputs and returns were priced in 1991 dollars to remove distortions due to inflation. Interest on the facility and livestock investment was charged at a six percent "real" or inflation-adjusted rate. Ownership costs were calculated based on straight line depreciation of the buildings over 15 years and the equipment over 8 years with no salvage value. The ownership costs including six percent real interest plus depreciation are $9.19 and $7.03 per hundredweight, respectively, for the small and large operations.

Labor was charged at $10 per hour. This is considerably higher than the average of $4.64 per hour reported for the week of October 7, 1990 in USDA's Farm Labor publication, even when 19.8 percent is added for workers' compensation. However, the average manufacturing wage in Minnesota is $10.96 per hour and $13.13 with workers' compensation (Clanton). Swine operators are experiencing problems recruiting skilled and reliable workers, and the higher manufacturing wage a better measure of the opportunity cost of workers capable of achieving the high performance levels assumed here.

The small operation shows a loss of $2.00 per hundredweight with interest on the facilities and livestock charged at six percent. The large operation shows a profit of $1.93 per hundredweight.

The rate of return on investment is very sensitive to the wage rate that is paid. Because the wage rate varies from one area to another, the rate of return on the investment in an average year was calculated at different hourly labor charges. The results are:

Hourly Labor Charge	Small Operation	Large Operation
$4.00	4.47%	9.68%
6.00	3.35	8.59
8.00	2.22	7.51
10.00	1.10	6.42
12.00	-0.02	5.34
14.00	-1.14	4.25

The return per hour of labor after depreciation and interest on investment over the economic life of the facility at different interest rates is:

Interest Rate	Small Operation	Large Operation
4%	$7.87	$17.54
6	5.82	15.39
8	3.78	13.24
10	1.73	11.09
12	-0.31	8.95

While the use of a real interest rate is useful for analyzing average profitability, nominal interest rates on borrowed capital must be considered in analyzing cash flows. Typically a producer uses accumulated equity to cover part of the cost of a new facility, and finances the rest. Return over feed and operating expenses was used to calculate the size of construction loan that can be serviced in an average year with a seven year term at 12 percent. The maximum amount of the investment that can be financed out of cash flow in the average year is 38 percent for the small operation, and 62 percent for the large size.

Table 3.7. Average Annual Costs and Returns, Small Baseline System

	Per Litter	Per Cwt. of Pork	Total Per Year
Value Produced			
Market hogs - 8.47, 241 lbs. @ $46	$938.72	44.87	$257,960
Cull sows and gilts - 0.23, 450 lbs. @ $38	38.94	1.86	10,701
Cull boars - 0.019, 450 lbs. @ $36.50	3.08	0.15	848
Total, 20.92 cwt.	$980.74	46.88	$269,507
Feed Requirements and Costs			
Corn, 109 bu. @ $2.40	$260.42	$12.45	$71,563
Supplement, 0.726 ton @ $320	232.22	11.10	63,814
Total, 3.60 lbs./lb. pork	$492.64	$23.55	$135,377
Operating Costs			
Marketing	$13.50	$0.65	$3,710
Replacement boars	11.25	0.54	3,092
Replacement gilts	62.50	2.99	17,175
Veterinary and medicine	31.00	1.48	8,519
Utilities, fuel and oil	30.00	1.43	8,244
Repairs	40.00	1.91	10,992
Supplies	12.00	0.57	3,298
Insurance, property taxes	29.31	1.40	8,053
Interest on operating capital	8.00	0.38	2,198
Total Operating	$237.56	$11.36	$65,281
Total Feed and Operating	$730.20	$34.91	$200,658
Return to Facility Investment, Labor, Management and Risk	$250.54	$11.98	$68,849
Facility Ownership Costs	$192.14	$9.19	$52,801
Labor 2,760 hrs. @ $10.00:	100.26	4.79	27,552
Total Listed Costs	$1,022.60	$48.88	$281,011
Return To Management and Risk	$-41.86	$-2.00	$-11,504

Table 3.8. Average Annual Costs and Returns, Large Baseline System

	Per Litter	Per Cwt. of Pork	Total Per Year
<u>Value Produced</u>			
Market hogs - 8.47, 241 lbs. @ $46	$938.72	$44.93	$1,142,466
Cull sows and gilts - 0.22, 450 lbs. @ $38	38.35	1.84	46,675
Cull boars - 0.012, 450 lbs. @ $36.50	2.03	0.10	2,474
Total, 20.81 cwt.	$979.10	$46.87	$1,191,615
<u>Feed Requirements and Costs</u>			
Corn, 108 bu. @ $2.40	$258.43	$12.37	$314,522
Supplement, 0.725 ton @ $320	231.90	11.10	282,235
Total, 3.58 lbs./lb. pork	490.33	23.47	596,757
<u>Operating Costs</u>			
Replacement boars	7.43	0.36	9,038
Replacement gilts	62.50	3.00	76,040
Insurance, property taxes	22.42	1.07	27,284
Other	134.50	6.43	163,719
Total Operating	$226.84	$10.86	$276,080
Total Feed and Operating	$717.17	$34.33	$872,837
Return to Facility Investment, Labor, Management and Risk	$261.93	$12.54	$318,778
<u>Facility Ownership Costs</u>	$146.92	$7.03	$178,814
<u>Labor</u> 9,093 hrs. @ $10.00:	$74.71	$3.58	$90,930
Total Listed Costs	$938.81	$44.94	$1,142,581
Return to Management and Risk	$40.29	$1.93	$49,034

4. Outdoor Production System

The welfare of animals is tied by many welfare advocates to their environment and ability to return to the natural state. Outdoor production is a more natural state than is confinement. Often the choice of an outdoor system is made by producers not so much out of animal welfare concerns, but rather to reduce capital necessary to enter into swine production. Niche markets for "Welfare Reared" animal meat products are developing which use outdoor production techniques as a qualifying factor.

For producers who meet the basic requirements for outdoor production and can maintain production figures that compare favorably with confinement, the outdoor alternative has the potential of being a viable alternative in the southern U.S. where the climate is mild enough for the outdoor farrowing facilities to be used year-round. Further north, however, where farrowing must either be suspended in the winter months or moved indoors, the economic viability of outdoor production is questionable. The facility investment is spread over reduced part-year production, increasing per unit costs. Because the outdoor facilities are only used part of the year, a lower quantity of pork is produced in a given size facility and facility cost per unit rises. To the southwest, low rainfall makes it more difficult to maintain good pastures.

McNabney provides a map that outlines those areas of the United States that have climates suitable for outdoor, year around farrowing. The region extends eastward from the southeast corner of Colorado, takes in the southeast and southwest tips of Kansas, includes the northern three fourths of Oklahoma, the southern one third of Missouri, all of Arkansas, northern Louisiana, the southern tips of Illinois and Indiana, all of Kentucky and Tennessee, all but the southern most regions of Mississippi, Alabama and Georgia, and all of South and North Carolina, as well as Virginia and West Virginia. A large area of western Oregon and a small portion of southwestern Washington state are also included. While outdoor farrowing and gestation are practiced in other areas, any form of continuous farrowing outdoors is expected to experience poorer litter performance outside of the area outlined. Those producers that do farrow and maintain the sow herd outdoors in the northern regions of the United States often practice a continuing rotation where first service gilts are culled and a new group is brought in. The lots are cleared by early fall and the process begins again the following spring (Hawton, personal communication). This necessitates a capital expenditure in farrowing facilities and equipment that is not spread over an entire year's production. Unless an outside source of hogs is secured as feeder pigs over the colder months, nursery and growing/finishing facilities and equipment also are under-utilized. Hogs on such operations are seldom the primary source of income.

Another requirement is a site with light, well drained soil. When making site selections for outdoor production, one must consider the health and well being of the pigs, as well as access to the paddocks for feed distribution, maintenance and observation. A ready supply of good quality, reasonably priced bedding is needed.

A third requirement is a line of hogs that is adapted to outdoor production and has shown an ability to maintain high levels of production and top quality carcasses in such systems. Bichard (1989) lists these requirements for the outdoor sow:

1. She must be hardy enough to survive outside in inclement weather.
2. She must be a good grazer to utilize the pasture.
3. She must be a good mother because she has to rear a litter without frequent attention or special penning.
4. She should not be too aggressive to stockmen and easy to move but willing to defend her territory.
5. She must be capable of producing progeny to meet the market's needs.

Some have suggested that a final requirement is a manager with a temperament more akin to a shepherd than a pig man (Anonymous). While still a pig man, the outdoor operator needs to be aware of husbandry practices suited to the outdoor working environment.

Great Britain provides an appropriate model to investigate when considering all aspects of outdoor pig production. The breeding herd is more often managed outdoors in Great Britain than the market animals. Often, the British farmer incorporates his hog operation into his crop rotation, annually rotating his sows onto that year's idle parcel so that the site for outdoor production changes from year to year. U.S. producers tend to try to operate in the same location for as long as possible (McNabney). A major problem with remaining on the same paddocks for long periods of time is the increased likelihood of soil borne parasite infestations. Pattison et al. indicates that the infestation of a nodular worm (*oesophagostomum*), could cause significant reductions in sow body weight, pigs born, pigs born alive and litter weights. In addition, it is reported that piglet weaning weight was lower despite increased creep feed consumption over the worm free control litters. The infected growing pig could be expected to require more feed for growth and reduced growth rates. In the case of the Pattison study, it is reported that, even with the significant reactions to the infestations, the hogs and sows displayed no clinical signs of infestation. In order to combat such infestations, an increase in the operating expense of veterinary and medicine is made for injectable parasite control.

Outdoor systems are analyzed for two situations:

1. A southern location where year-round farrowing is practiced and breeding and gestation as well as farrowing is done in outdoor paddocks, and

2. A northern (Minnesota) location where outdoor farrowing is done only four months of the year, with all gilts sold after one litter.

The main geographic focus of this analysis is Minnesota and the Upper Midwest, and the northern all-gilt system is considered for that reason. The southern location is included because of the resurgence of interest in outdoor farrowing in the south, and to demonstrate the impact of using the facilities there year-round compared to only part of the year in Minnesota. Nursery and growing/finishing facilities are confinement buildings similar to the baseline in both situations. Only the large operation results are discussed. The relative profitability of the small size outdoor system compared to the baseline is not expected to differ significantly from the large size, and is not discussed further for that reason.

One question that arises with all-gilt, summer farrowing and confinement finishing is how to utilize the finishing facilities the rest of the year. If only a few Minnesota producers returned to summer farrowing outdoors, they would probably buy feeder pigs to keep the finishing facilities full. However, if outdoor farrowing were adopted widely, feeder pig availability would become more seasonal and the finishing facilities would likely be idle for part of the year. To evaluate the impact of such seasonality, the finishing facilities in the Minnesota situation are first assumed to be used for breeding and gestating gilts for the next year when not used to feed the pigs farrowed in the four-month summer period. Then feeder pigs are assumed to be purchased to fill the extra finishing space not used by the gilts and boars. Also, purchased feeder pigs introduce additional disease risk that may reduce performance periodically.

4.1 <u>Outdoor System Performance</u>

Production for such a system in the United States is difficult to estimate. Pigs weaned per litter and litters per sow per year would be expected to favor the indoor/intensive system. It has been previously stated that any farrowing system that allows the sow near total freedom of movement will cause a reduction of one pig weaned per litter when compared to a system utilizing farrowing stalls. British records provide an excellent comparison between the two systems, but the fact that the British have been honing the craft of outdoor production for a number of years puts their latest data, presumably, ahead of what might be achieved in this country, at least initially. For instance, Bichard et al. uses data from MLC Pigplan, a British swine production record system, from 1987 to compare production between indoor and outdoor production in England. That data shows only a slight advantage in litter performance for the indoor system. In litters per sow per year, pigs weaned per litter, and pigs weaned per sow per year the outdoor system shows 2.2, 9.1 and 20.1 respectively while the indoor system's data shows 2.27, 9.4 and 21.4 for the same three measures of productivity. If much of the improvement in British outdoor production is due to genetics, then that genetics should be readily available and it could be assumed that current production figures out of England could be achieved here immediately.

For the purposes of this analysis, however, it is assumed that lower production would be achieved in a United States outdoor production system than the most current British production figures show, even with available genetics, because experience in husbandry would be lacking. For this reason, Hawton's estimate of a one pig reduction per litter was utilized in this analysis for the southern operation where F1 replacement gilts are purchased and kept for four parities. Eight pigs are weaned per litter versus the nine in the baseline. Litters per sow per year are reduced by three percent, to 2.34 compared to the baseline 2.41, in line with the data above. In the northern all-gilt system, replacement gilts are kept from the operation's pig crop from the previous year. Some heterosis will probably be lost by raising gilts. Gilts will also probably have smaller litters than sows aside from the heterosis effect, so pigs weaned per litter is reduced further to 7.5 for the northern operation to account for both the reduced heterosis and gilt effects.

4.2 Outdoor System Description

Production layout, acreage requirements and equipment for the southern year-round system is taken from Bichard et al. The layout consists of quartered paddocks divided by access roads. The layout is adjusted to reflect a 500 sow herd.

The schedule in the southern system is for weekly farrowing, so every week 24 sows are weaned, twelve early in the week and twelve midweek. At each weaning the sows are split by size and condition into two paddocks containing six sows each. At the end of one week (post weaning), the paddocks are combined to hold 12 sows and two to three boars are introduced. On a four week servicing pattern, eight paddocks of 1.25 acres are required.

The dry sow area consists of paddocks holding 12 sows per paddock. One or more boars run with the sows for the first four to ten weeks to catch any repeats to heat. The sows remain in this area for 14 weeks so 30 paddocks of 1.25 acres each are required, with three huts in each paddock.

The farrowing area consists of 20 paddocks of 0.6 acre, each containing 6 sows. Sows enter the farrowing paddocks two weeks prior to farrowing to allow for acclimation. A three week weaning target date is assumed.

A group of newly weaned gilts is introduced into the breeding herd every month. Gilts remain on these paddocks for eight months so eight paddocks of 1.25 acres each are needed. Near the end of their stay in these "introductory" paddocks, the gilts are exposed to boars. After their eight month stay, they are moved to the farrowing area. The replacement gilts are priced at $250, as in the baseline. This price is assumed to cover the cost of feed, labor and operating inputs up to 220 pounds because hybrid F1 gilts are not typically purchased at weaning as assumed here. The southern, year-round farrowing system requires a total of 70 acres of pasture land for breeding, gestation and farrowing.

The nursery, growing and finishing buildings are assumed to be of the same totally enclosed, mechanically ventilated design as in the baseline. For the southern system, the nursery, growing and finishing building costs per head are reduced 22 percent below the baseline, the difference in construction costs in the major hog producing areas of North Carolina compared to southern Minnesota as indicated by the location multipliers in Boeckh, with the totals reduced by the differences in pigs weaned per sow and sows in the herd. In the northern system, these facilities are priced using the same cost per head capacity as in the large baseline system.

Bichard et al. indicate that British outdoor operations of the type described strive for a three-week weaning age. In line with this information, weaning age for the southern system was kept at the same 24 days as in the baseline. American outdoor operations commonly wean later, at four to six weeks. Delayed weaning beyond the assumed 24 days would reduce the size of the expensive nursery facility. More farrowing huts would be required, however, but would cost less than the savings in the nursery. The main disadvantage of delayed weaning in the year-round system is less efficient utilization of the breeding herd investment. Litters per sow per year would be reduced by the delayed weaning and breedback, reducing total market animals produced in the operation or increasing the number of sows required, and reducing feed efficiency in either case. An analysis not shown in detail here showed that the net effect of delayed weaning on per hundredweight production costs in the southern system is negligible, only one cent per hundredweight different from early weaning.

Delayed weaning is more economically advantageous in the all-gilt northern system. Each gilt produces only one litter regardless of weaning age, so that breeding herd utilization and feed efficiency is not affected by the delay. Weaning age is set at 35 days in the northern system, resulting in a nursery capacity of 1,134 pigs, or 61 percent of the size of the baseline nursery.

Manure in the nursery and growing/finishing stages is handled as a liquid as in the baseline. Because less liquid manure is being produced compared to the baseline, however, it was assumed to be pumped and spread by a custom applicator rather than owning liquid manure handling equipment.

In the northern, summer farrowing system, the farrowing facilities are the same as for the southern system. The land requirement is reduced to 26.5 acres because only farrowing takes place outdoors.

4.3 Outdoor System Investment

The equipment, prices and investment for the outdoor stages of the systems are provided in Table 4.1. Table 4.2 shows the capacities required and the building investment per head for the nursery and growing/finishing stages, as adjusted by size and the difference in construction costs at the southern location. Total land, building and equipment investments are shown in Table 4.3. Equipment prices are taken from Bichard et al. as well as university extension materials and vendor estimates. Water equipment, feeders and fencing costs are also reduced in the summer system because only farrowing takes place outside, not breeding or gestation. The outdoor equipment for the year-round system requires an investment of $300 per sow, compared to only $107 for summer farrowing. However, the total building and equipment for the southern system is $1,805 per sow compared to $1,445 for the northern outdoor system and $2,770 for the large baseline system. Total investment is $2,381 per sow for the southern system and $1,748 for the northern one compared to the baseline $3,320. Total investment in the northern, all gilt system is lower than in the southern, year-round one because the raised breeding gilts are valued at lower prices than are the purchased F1 gilts, and because they are only owned for part of the year. Sale of the breeding herd can help to finance ownership of the market animals that are owned the rest of the year.

Table 4.1. Outdoor Equipment Requirement and Investment, 500 Sow Herd.

Item	Unit	Number	Price	Total
Year-round Farrowing, Southern Location				
Farrowing huts	hut	120	$150	$18,000
Gestation huts	hut	90	800	72,000
Farrowing hut equipment[a]	hut	120	120	14,400
Water equipment	paddock	66	152	10,000
Feeders	paddock	66	360	23,760
Fencing	sow	500	3	1,500
Loader	each	1	4,400	$4,400
All terrain vehicle	each	2	2,000	4,000
Livestock/straw trailer	each	1	2,000	2,000
Total				$150,060
Per sow				$300[b]
Summer Farrowing, Minnesota				
Farrowing huts	hut	120	$150	$18,000
Farrowing hut equipment[a]	hut	120	120	14,400
Water equipment	sow	20	152	3,040
Feeders	paddock	20	360	7,200
Fencing	sow	120	3	360
Loader	each	1	4,400	$4,400
All terrain vehicle	each	2	2,000	4,000
Livestock/straw trailer	each	1	2,000	2,000
Total				$53,400
Per sow				$107

[a]Includes fenders and curtains (cost can be reduced by moving equipment from hut to hut as needed).

[b]Equipment for the boars and gilt pool were included with the gestating sows rather than being priced separately as in the confinement systems calculations.

Table 4.2. Prices Used for Nursery and Growing/Finishing Building Investment Calculations, Outdoor Systems

	Units	Stage: Nursery		Stage: Growing/Finishing	
Southern	foot^2	(1,648 hd.)	$6.77	(3,024 hd.)	$10.33
	head		35.55		81.57
Northern	foot^2	(1,134 hd.)	9.73	(2,610 hd.)	13.24
	head		51.07		104.67

Table 4.3. Investment Requirement for the Outdoor System

	Buildings	Equipment	Total	Per Pig Place
Southern, Year-Round Farrowing				
Land, 70 Acres @ $500			$35,000	
Facilities:				
Breeding/Gestation /Farrowing	$0	$150,060	$150,060	$300
Nursery	58,590	115,574	174,164	106
Growing-Finishing	246,669	97,978	344,647	114
Manure Storage	107,575	0	107,575	
Feed Mill and Grain Storage	75,150	20,100	95,250	
Miscellaneous Equipment	0	31,000	31,000	
Total Facilities	$487,984	$414,652	$902,696	
Per Sow	$976	$829	$1,805	
Livestock:				
Sows (500 head @ $250)			$125,000	
Gilt Pool (42 @ 250)			10,500	
Boars (25 @ 600)			15,000	
Market Animals (2,630 @ 39)			102,580	
Total Livestock (3,202)			$253,080	
Total Investment			$1,190,716	
Per Sow				$2,381
Northern, Summer Farrowing				
Land, 26.50 Acres @ $1,000			$26,500	
Facilities:				
Farrowing	$0	$53,400	$53,400	$107
Nursery	57,914	79,527	137,442	121
Growing/Finishing/Breeding/ Gestation	273,177	84,564	357,741	137
Manure Storage	91,435	0	91,435	
Feed Mill and Grain Storage	31,409	20,100	51,509	
Miscellaneous Equipment	0	31,000	31,000	
Total Facilities		$453,934	$268,691	$722,526
Per Sow	$908	$537	$1,445	
Livestock:				
Gilts (500 head @ $138)			$69,000	
Boars (25 @ 600)			15,000	
Market Animals (1,054 @ 39)			41,098	
Total Livestock (1,579)			$125,098	
Total Investment			$874,224	
Per Sow				$1,748

4.4 Outdoor System Feeding and Growth Performance

Feed requirements in an outdoor system are expected to be higher than in a confinement system due to increased activity and the changeable environment (Anonymous, in Pig Farming). Kliebenstein and Kirtley (1980) reported a drop in whole herd feed efficiency of nearly 12 percent in a pasture system as compared to a large confinement system. It appears that this pasture system fed market hogs outdoors as well as the breeding herd. Kliebenstein reported also that even with the lower feed efficiency, overall feed costs were quite similar between the pasture system and the confinement systems analyzed in his report. Bichard et al. reports that English feed manufacturers produce sow feed in the form of cobs, biscuits and rolls that reduce waste. As the United States has a fair amount of experience in outdoor sow maintenance on dry lot, a compensation for climatic conditions was the main consideration.

This analysis assigns a ten percent addition in pounds of feed per day for the gestating sow and gilt as well as the boar over the baseline confinement system feeding program shown in Table 3.2. The lactating sow receives an additional 0.05 pounds of feed per pig suckled, but with the one pig drop in litter size the total pounds per lactating sow drops slightly. Days to weaning in the southern location are similar to the baseline so nursery feed is the same. Growing and finishing requirements are also the same on a per pig basis. The increased feed for the breeding herd reduces the whole-herd feed efficiency to 3.66, two percent worse than the large baseline system.

Feed efficiency drops further in the northern system because of the further drop in litter size to 7.5 and the 11 day delay in weaning age to 35 days. Also, gilts are in the gilt pool for 50 days instead of the baseline 30 in order to give a complete 365 day birth-to-farrowing interval. The whole herd feed efficiency falls to 3.79 with these changes. Other factors such as nutritional contributions from the pastures were not explicitly considered.

4.5 Outdoor System Labor Requirements

A potential benefit of the outdoor system is that it gives the manager the flexibility to substitute labor for capital investment. McFate (1979) estimates the difference in monthly labor for confinement farrowing versus individual house as 84 minutes versus 98 minutes respectively per litter, a 17 percent increase for the individual house. Kliebenstein and Sleper estimate the per sow labor requirements for a confinement system to be seventy five percent of the pasture system. But Kliebenstein and Kirtley (1980) found that labor expended per hundred pounds of pork was slightly lower for a pasture system than a confinement system. McNabney (1990) quotes British consultant Keith Thornton as estimating three men being needed for a 500 sow herd on an outdoor system similar to that outlined here. The three man estimate is in line with current labor requirement estimates for confinement systems with similar size herds. One advantage that the British have over the United States is the utilization of intact males as market hogs. The chore of castration is more difficult and time consuming in an outdoor system.

It would seem that the outdoor system would require additional labor over the confinement system for several reasons: 1) The movement of sows is more difficult. 2) The greater expanse of the system makes observation more time consuming. Of course, outdoor production is designed to provide the types of freedom to the sow that negate the requirement for constant observation. Observation, even during farrowing, is not as essential as in a confinement system. 3) Feed delivery is much more labor intensive, even with the most studied paddock layout. On the other hand, much of the labor for manure removal is eliminated in the outdoor system.

Table 4.4 shows labor per sow per year assumed for the two outdoor systems. For the southern system where breeding, gestation and farrowing are all outside, labor for all three stages is increased 17 percent from the baseline, based on McFate et al. Nursery and grow/finish hours per pig finished are the same as in the baseline. The result is a total labor per sow per year 4.8 percent higher than the baseline.

For the northern system where the growing/finishing unit is used for breeding and gestation after the market animals are sold, the breeding/gestation labor per litter was assumed to be the same as in the baseline, 1.49 hours per litter. This may be a slight underestimate as no semi-automated feed delivery system has been included to hand-feed the breeding animals, but no information is available on how much additional labor would be needed. The gilts spend 39 percent more days in the farrowing stage compared to the southern operation because of the delay in weaning, and the nursery stage is 22 percent shorter. Farrowing labor is increased and nursery labor is decreased proportionally. Total labor hours per gilt per year are 8.77, only 49 percent of those for the baseline 18, but because far fewer pigs are produced with summer farrowing only, labor hours and cost per hundredweight are 37 percent higher.

Table 4.4. Annual Labor Requirements by Stage for the Outdoor System, Southern and Northern Locations

	Location	
	Southern	Northern
	hours per sow per year	
Stage		
Farrowing alone	-	4.86
Farrowing-Breeding-Gestation	12.27	-
Nursery	3.50	1.17
Growing-Finishing	3.10	1.25
Breeding-Gestation	-	1.49
Total	18.87	8.77

4.6 Outdoor System Economic Costs and Returns

Annual costs and returns for the outdoor systems are shown in Tables 4.5 and 4.6. Value produced per litter is down from the baseline because of the smaller litter size. Feed cost per hundredweight of pork produced is estimated at $24.31 for the southern outdoor system and $24.71 for the northern outdoor one, versus the $23.47 of the large baseline confinement system.

Higher feed costs are a disadvantage of some southern locations that may offset lower facility costs. Corn prices received by farmers in Missouri and Arkansas, states close to shipping routes but still warm enough for year-round outdoor farrowing, are about the same as in Minnesota. Cost to ship corn from the Midwest to North Carolina, however, is estimated at 50-60 cents per bushel. Large operators may ship for 10-15 cents less. North Carolina producers may also buy local corn at prices that are sometimes below Midwest prices. North Carolina corn prices received by farmers averaged 32 cents higher than Minnesota between 1982 and 1989 (Clanton). Soybean meal for the supplement is likely to cost the same near processing plants in the major southern livestock and poultry production areas of the south as in the Midwest. In more marginal livestock areas such as Georgia where processing plants are not nearby, supplement prices will also be higher. In an area where corn cost 40 cents more than the $2.40 used here, feed cost per hundredweight of pork produced would be $26.10, or $2.63 more than the baseline.

Straw requirements for this alternative are determined by assuming 35 pounds of straw (oat) are used per 100 pounds of moisture (Ensminger). For the farrowing phase, this works out to 11.3 pounds per day per litter. For the gestation phase, three pounds per day per dry sow was the estimate. Straw is priced at $65 per ton, resulting in a bedding cost of $21 dollars per litter for the southern operation and $14 for the northern one.

Other changes in this alternative from the baseline system are in custom hiring of liquid manure pumping and spreading, veterinary costs, and utilities. Costs of custom hired manure pumping and application were set at $1.70 per litter, based on unpublished data from the Minnesota Farm Custom Rate Survey conducted in December, 1990 (see Lazarus and Fuller for a description of the survey). An injectable treatment that would control both internal and external parasites may have to be administered to gestating sows on a monthly basis to control parasites in the southern United States, at a cost of approximately one dollar per treatment. A five dollar per litter cost is added to the baseline veterinary and medicine costs for the southern system to cover this cost. The parasite treatment is reduced to $2.50 per litter for the northern system. Utilities decline eight dollars per litter from the baseline to $22 after the adjustment for the cost of mechanical ventilation in the baseline breeding herd.

In the southern outdoor system, return to management and risk is $-0.08 per hundredweight compared to the baseline $1.93. This outdoor system then appears slightly less profitable than the baseline, but close enough that small reductions in cost or improvements in efficiency could make it comparable to the baseline system. A 40 cents per bushel higher corn price would reduce returns to management and risk to $-2.19 per hundredweight. If the same weaned litter size could be achieved with the southern outdoor system as with the baseline, nine pigs per litter, return would also be comparable at $2.05. The other differences in capital and labor requirements and feed consumption thus appear to cancel each other out.

The northern summer farrowing analysis shows vividly the impact of only utilizing the facilities for part of the year on costs per hundredweight. Facility ownership costs are $10.62 per hundredweight, compared to $5.91 in the southern outdoor system and $7.03 in the baseline. In reality, a producer utilizing the finishing facilities only part of the year may build cheaper facilities than those assumed here and reduce ownership costs somewhat, but then feed and labor efficiency would also probably suffer, increasing those costs well above the levels assumed here. The $-6.21 per hundredweight loss in the northern outdoor system illustrates why outdoor systems are no longer used by many producers in Minnesota.

After the raised market animals are sold in the northern operation, there will be finishing capacity for 1,408 finishing animals after allowing room in the growing/finishing facility for the replacement gilts and boars. Table 4.7 is a budget for finishing one batch of purchased feeder pigs per year in this unused space. Operating expenses are from Fales. Feed quantities are from Table 3.2 with the nursery feed adjusted to a starting weight of 40 pounds. The finishing enterprise contributes $16,282 over feed, operating and labor expenses. Gain on the purchased animals is 2,816 hundredweights. The farrow-to-finish enterprise produces 8,936 hundredweights of pork. Return to management and risk averaged over all 11,752 hundredweights is $-3.33 per hundredweight, if purchased feeder pigs are available.

Improved sow productivity would bring the northern system nearly to a breakeven profitability situation but still leave it less profitable than the baseline and southern systems. Weaning nine pigs per litter would produce a return to management and risk of $-2.56 per hundredweight for the farrow-to-finish enterprise or $-0.81 with the addition of the purchased feeder pigs.

Table 4.5. Average Annual Costs and Returns, 500 Sow Year-Round Outdoor System, Southern Location

	Per Litter	Per Cwt. of Pork	Total Per Year
Value Produced			
Market hogs - 7.53, 241 lbs. @ $46	$834.42	$44.81	$976,266
Cull sows and gilts - 0.224, 450 lbs. @ $38	38.23	2.05	44,717
Cull Boars - 0.013, 450 lbs. @ $36.50	2.05	0.11	2,402
Total, 18.62 cwt.	$874.69	$46.98	$1,023,385
Feed Requirements and Costs			
Corn @ $2.40	235.68	12.66	$275,750
Supplement @ $320	211.11	11.34	246,996
Total Feed	446.79	23.99	$522,745
Operating Costs			
Replacement boars	$7.50	$0.40	$8,775
Replacement gilts	62.50	3.36	73,125
Veterinary and medicine	36.00	1.93	42,120
Straw	21.00	1.13	24,570
Custom manure spreading	1.70	0.09	1,989
Utilities, fuel and oil	22.00	1.18	25,740
Insurance, property taxes	16.11	0.87	18,852
Other	72.00	3.86	84,240
Total operating	$238.81	$12.83	$279,411
Total Feed and Operating	$685.60	$36.82	$802,156
Return to Facility Investment, Labor, Management and Risk	$189.08	$10.15	$221,229
Facility Ownership Costs	$110.02	$5.91	$128,728
Labor, 9,435 hrs. @ $10.00:	$80.64	$4.33	$94,348
Total Listed Costs	$876.27	$47.06	$1,025,232
Return to Management and Risk	$-1.58	$-0.08	$-1,847

Table 4.6. Average Annual Costs and Returns, 500 Sow Outdoor System, Summer Farrowing, Northern Location

	Per Litter	Per Cwt. of Pork	Total Per Year
<u>Value Produced</u>			
Market hogs - 6.06, 240 lbs. @ $46	$666.44	$37.38	$333,218
Cull sows and gilts - 0.938, 350 lbs. @ $38	124.75	7.00	62,377
Cull Boars - 0.030, 450 lbs. @ $36.50	4.95	0.28	2,474
Total, 17.83 cwt.	$796.14	$44.65	$398,069
<u>Feed Requirements and Costs</u>			
Corn @ $2.40	234.51	13.15	$117,253
Supplement @ $320	206.15	11.56	103,073
Total Feed	440.65	24.71	$220,326
<u>Operating Costs</u>			
Marketing	$11.25	$0.63	$5,625
Replacement boars	18.08	1.01	9,038
Veterinary and medicine	33.50	1.88	16,750
Straw	14.00	0.79	7,000
Custom manure spreading	1.70	0.10	850
Utilities, fuel and oil	22.00	1.23	11,000
Fire and wind insurance	16.28	0.91	8,141
Property taxes	11.75	0.66	5,873
Other	73.00	4.68	36,500
Total operating	$189.13	$10.61	$94,566
Total Feed and Operating	$629.78	$35.32	$314,892
Return to Facility Investment, Labor, Management and Risk	$166.35	$9.33	$83,177
<u>Facility Ownership Costs</u>	$189.35	$10.62	$94,676
Labor, 4,383 hrs. @ $10.00:	$87.66	$4.92	$43,829
Total Listed Costs	$906.79	$50.86	$453,397
Return to Management and Risk	$-110.66	$-6.21	$-55,329

Table 4.7. Costs and Returns for Feeding 1,408 Purchased 40 Pound Feeder Pigs to 240 Pounds After Raised Pigs are Sold, Outdoor System, Northern Location

	Per Head	Per Cwt. of Gain	Total Per Year
Value Produced			
Market hog - 240 lbs. @ $46	$110.40	$55.20	$155,443
Feed Requirements and Costs			
Corn @ $2.40	24.04	12.02	$33,852
Supplement @ $320	20.64	10.32	29,061
Total Feed	44.68	22.34	$62,913
Operating Costs			
Purchase price	$39.00	$19.50	$54,912
Allowance for 3% death loss	1.17	0.59	1,647
Interest on feeder pig, 11% for 121 days	1.42	0.71	2,002
Custom manure spreading	1.70	0.10	850
Marketing & buying expenses	3.00	1.50	4,224
Other related expenses	8.00	4.00	11,264
Total operating	$52.59	$26.30	$74,050
Total Feed and Operating	$97.28	$48.64	$136,963
Return to Facility Investment, Labor, Management and Risk	$13.12	$6.56	$18,480
Labor, 0.16 hrs. @ $10.00:	$1.56	$0.78	$2,198
Total Listed Costs	$98.84	$49.42	$139,161
Return to Management and Risk	$11.56	$5.78	$16,282

5. Turnaround Gestation Stall

Single sow confinement has several advantages. It prevents the inevitable fighting that occurs in group housing. More importantly, it provides for precision feeding of individual sows, preventing over-conditioning while reducing feed bills. The design of the modern gestation barn allows for mechanical feed delivery and waste removal, reducing labor requirements. This type of facility limits labor use to daily observation of sows, equipment maintenance and the transferring of sows from stage to stage.

With modern swine confinement, the sow is often in a crate or stall on an almost continuous basis. Such stalls and crates fail to offer the sow the freedoms welfarists say she is entitled to, those being the ability to lie down and get up with ease, to stretch its limbs and the ability to groom itself (Sainsbury). The need to be able to turn around might be a behavioral need although there is some debate whether deprivation of the ability to turn inhibits a strong desire (McFarlane et al.).

Alternative technologies are being developed that permit precision feeding of the sow, that have similar labor and investment requirements to the baseline system, and that proponents claim alleviates some of the welfare concerns. One such example is the "MoorComfort" turnaround stall, designed so the rear two-thirds of the stall can swing, thus allowing individual sows to turn. The sow that desires to turn must rely on a certain amount of cooperation from its neighbor, but research has shown that sows learn the system rather quickly and will move forward to allow the neighboring pig to turn. Research has shown that when given the opportunity, sows, on average, will turn nearly 24 times in a 24 hour period (Curtis).

The use of the stall is not restricted to the gestation barn. It can also substitute for the conventional individual stall in the breeding barn.

5.1 Turnaround Gestation Stall System Sizing

The design allows for stalls to be butted up against one another, thus reducing space requirements over facilities with alleys between each row of stalls, because one alley can be eliminated for each two rows of stalls. Such a design could allow up to an 11 percent reduction in space (Curtis). In this comparative analysis, the large operation is given the full 11 percent reduction from the conventional system, assuming four rows of stalls, to 20 square feet per sow in breeding and gestation. The small operation is assumed to have three rows of stalls, so is given a 5.5 percent space requirement reduction because only one alley is eliminated in the building instead of two, to 21 square feet per sow in these two stages. The ability to butt the stalls up against one another also allows for sows to socially interact when a number are turned to the rear of the stall. With a butt to butt configuration, up to 10 pigs can meet at the rear of their individual stalls and socially interact, thus satisfying another welfare concern (Curtis). The system is partially slatted with the forward portion of the stall being solid flooring.

5.2 Turnaround Gestation Stall Investment

The turnaround stalls are available commercially. The Livestock Equipment Division of Moorman's Manufacturing reports a basic range in price for the stall of $115 to $160 (personal communication). The midpoint of the range, $137.50, is used in this analysis, compared to $100 per sow for the gestation and breeding barns of the baseline system. The $200 per sow stalls and pens cost shown in Table 3.5 for the baseline breeding barn includes another $100 per sow for breeding and holding pens. This component was kept the same in the turnaround stall system, bringing the total to $237.50. Boar stalls were assumed to cost $200, the same as in the baseline.

The savings in building area does not translate into as great a reduction in building cost because the manure storage remains the same. The large operation's gestation building cost per square foot increases slightly to $14.08 compared to $13.62 in the baseline, because of its smaller size. The breeding buildings and the smaller operation's gestation building cost the same per square foot as the baseline. The turnaround stall system increases the building and equipment investment required for the breeding and gestation facilities by less than one percent, to $3,539 per sow in the small operation and $2,850 in the large one compared to the baseline (Table 5.1). Total investment is $4,147 and $3,400 for the two sizes. If the turnaround stall design becomes popular, manufacturing economies and lower prices may result, which could make this alternative more attractive than this analysis suggests.

Production for this alternative is considered to be the same as the baseline system in this analysis. Advocates of exercise for sows during the dry period might argue the additional activity increases the number of pigs born alive and weaned. However, research documenting production enhancement with such a gestation system is, as yet, unavailable.

In evaluating the system, a producer noted that more labor would be required to observe sows as they are introduced into the system. The additional labor should only be needed over the first few days of the gestation period. Labor per sow was increased five minutes in the gestating phase for the turnaround alternative to allow for the increased observation time.

A potential problem with the turnaround stall is the method of feed delivery to the sow. The need for the sow to step forward to allow a neighboring sow to turn and the need to use the forward area to turn seems to preclude the use of the conventional feed bowl or pan. Floor feeding with its potential for feed wastage is assumed in this analysis. Gadd (1990) reports that such a system has the potential to require 15 percent additional feed to account for wastage. Research with the turnaround stall does not indicate a problem of dunging in the forward area, however, and by feeding the sow portions she will clean up as fed, a 10 percent increase in feed is deemed as the outer range of feed wastage (Hawton, personal communication). In this analysis, feed was increased 10 percent to the gestating sow to allow for wastage.

Table 5.1. Investment Requirement for the Turnaround Stall System

	Buildings	Equipment	Total	Per Pig Place
Small				
Land, 2.5 Acres			$2,500	
Facilities:				
Farrowing	$42,865	$11,648	$54,513	$1,704
Nursery	28,270	34,714	62,985	127
Growing/Finishing	82,552	22,291	104,843	152
Breeding	30,772	15,612	46,384	947
Gestation	35,457	22,393	57,850	590
Manure Storage	38,351	0	38,351	
Feed Mill and Grain Storage	19,683	18,500	38,183	
Miscellaneous Equipment	0	17,785	17,785	
Total Facilities	$277,950	$142,944	$420,894	
Per sow	$2,316	$1,191	$3,507	
Livestock:				
Sows (120 head @ $250)			$30,000	
Boars (9 @ 600)			5,400	
Gilt Pool (34 @ 250)			8,500	
Market Animals (682 @ 39)			26,608	
Total Livestock (845)			$70,508	
Total Investment			$493,901	
Per Sow				$4,116
Large				
Land, 5.7 Acres			$5,700	
Facilities:				
Farrowing	$136,931	$43,680	$180,611	$1,525
Nursery	84,504	130,021	214,525	116
Growing/Finishing	341,442	105,883	447,325	142
Breeding	71,209	47,888	119,097	815
Gestation	90,234	73,577	163,811	503
Manure Storage	116,250	0	116,250	
Feed Mill and Grain Storage	86,889	55,000	141,889	
Miscellaneous Equipment	0	22,511	22,511	
Total Facilities	$927,460	$478,560	$1,406,020	
Per Sow	$1,837	$948	$2,784	
Livestock:				
Sows (505 head @ $250)			$126,250	
Boars (26 @ 600)			15,000	
Gilt Pool (42 @ 250)			10,500	
Market Animals (3,078 @ 39)			120,044	
Total Livestock (3,651)			$271,794	
Total Investment			$1,716,862	
Per Sow				$3,400

5.3 Turnaround Gestation Stall Economic Costs and Returns

Table 5.2 shows that the turnaround stall used in the breeding and gestation facilities has little impact on cost per hundredweight of pork. Fire and wind insurance on the gestation and breeding facilities at one percent, property taxes at 1.5 percent, repairs at 3 percent of replacement value, and depreciation and interest on investment are the facility costs considered likely to differ with the turnaround stall system. For the small operation, the overall impact, considering feed, operating, ownership and labor costs, is an increase of $0.37 per hundredweight of pork. For the large operation, the increase in cost totals $0.32 per hundredweight. Most of this increased cost is because of the ten percent increase in wasted feed for the sows in breeding and gestation and for the gilt pool. Costs increase by only $0.10 for the large operation if feed consumption is assumed to be no more than in the baseline.

6. Electronic Sow Feeders

Precision feeding of dry sows is important to avoid feed wastage and to leave the sow in good condition at farrowing time. Group ad lib feeding leads to dominant individuals over eating and fighting. Skip or interval feeding creates much the same problem with less than positive results (Singleton) and is not recommended for gilts (Michel et al.). The use of electronic sow feeders (ESF) is a means of delivering the desired quantities of feed to individual sows while allowing freedom of movement in group settings.

Computer feeding of gestating swine has been used extensively in Europe with mixed results. The initial efforts appeared to be just a passing fad. Labor involved in monitoring the systems and a general feeling that they were unreliable weighed heavily against their viability on a widespread commercial basis. More recently, it appears that many of the wrinkles have been worked out and reliability is less suspect. In addition, many systems provide records on feed consumption and other variables of help in managing the breeding herd.

Initial ESF designs involved transponders attached to collars around the sow's neck, which were often lost. A more recent design has the transponder mounted in an ear tag, which is lost much less frequently (0.29 ear tag lost per first parity gilt on average, compared to 1.31 collar lost per gilt). Losses are less in older sows. The latest design under development in the Netherlands has the transponder inserted under the skin when the pig is small, where it remains throughout its life (Backus).

Unless one desires a feeding station for each group of sows or some sort of automated gate system that releases groups by pen, electronic sow feeding seems best suited to loose housing of the sow groups. This allows the groups to intermingle, enhancing exercise and welfare. Sows tend to fight more in group housing. An additional disadvantage is the inability to practice all in/all out sanitation, but anecdotal evidence suggests that most producers with gestation stalls do not practice all in/all out sanitation in the gestation facility anyway.

Table 5.2. Average Annual Cost With The Turnaround Stall System

Item	Small	Large
Feed	$136,589	$602,154
Operating	65,335	276,205
Facility Ownership	$53,405	180,481
Labor	27,781	91,944
Total Feed, Operating, Ownership and Labor Costs	$283,111	$1,150,742
Per Litter	$1,030	$945
Per Hundredweight of Pork	$49.25	$45.26

Straw is often incorporated into such systems to reduce tedium and fighting (Clanton). Whether straw is a necessity is questionable. Singleton used no straw and yet recorded positive results. The very act of movement to and entering of the station might provide enough divergence of activity to alleviate boredom and related stress. A recent Netherlands design uses straw in the area where sows are first introduced into the group, where fighting is the greatest, but not in the main gestation housing area. Temporary partitions when sows are first introduced to the gestation building help to establish dominance rankings and reduce fighting, as does computer programming that only allows subgroups of sows to feed at different times of the day within the overall group (Backus, personal communication). Researchers at the University of Guelph recommend ESF only when straw is used (Miller, 1989).

Given the lack of evidence on whether and how much straw is necessary, it was not included in this analysis. Pens were established through partitions, but access was unlimited. Pens were partially slatted as were walkways. The configuration permits the use of scrapers for manure removal. The analysis assumes a new building, although some producers may be able to modify an existing structure to lower the initial investment costs (Clanton).

Variations in gestation, breeding and farrowing facility design that incorporate groups of sows, ESF and other electronic sensors and controls are being researched (Morris and Hurnik; Gadd). One such design for which information is available is the Hurnik-Morris (H-M) system. The H-M system includes the breeding and gestation phases. While seeking to maintain the most productive aspects of modern dry sow confinement, the system is specifically designed to allow the animal a broader spectrum of behavioral activities by providing freedom of movement, social interaction, exercise, socially synchronized eating and resting and reduced competition (Morris et al.). Animal welfare is the prime concern in the development of the system. As the system is of recent origin, and is currently being studied at Ridgetown College of Agricultural Technology, Ridgetown, Ontario, Canada, only preliminary data is currently available as to its production capabilities and commercial applications.

The H-M system utilizes electronic sow feeding for feed delivery and record keeping, electronic gate opening devices to allow access to feed stations while maintaining group integrity and computer controlled encouragement gates to move sows through the system while reducing labor requirements. The routine of a single feeding begins with the computer directed opening of the gate to the first group's pen and the rear entry gate of the feed stations. As an individual sow enters a station, her transponder number is identified and the rear gate closes. The sow is fed a portion of her daily allotment for that particular feeding. At the completion of that feeding interval the sow is released through a front exit. If the sow should not exit after the exit gate opens, a mild surge of electrical impulse equivalent to an electric fence encourages her to leave. Upon exiting, the sow enters an alleyway where she is allowed a predetermined amount of time to intermingle with mates, to roam, or to interact with boars which are penned between the feed station exits and the sow pen access gates. Any interaction with a boar is identified by an antennae in front of the boar pen so that the sow may be singled out as possibly in estrus. Identified sows are listed daily to assist the manager in estrus detection and timing of breeding. Following the predetermined post feeding time, a computer controlled encouragement gate moves any sows still in the alley back to their pens. Upon exiting of the feed stations by the first group, the next group is released and the process continues until all groups are fed and have returned to their pens. Subsequent feedings provide another portion of the daily diet until daily requirements are met. A daily feeding report is printed which indicates the amount of feed each sow consumes, or any sows that were off feed or did not eat their entire daily ration (Morris et al.).

The H-M system is said to offer benefits such as (J. R. Morris, personal communication):

- the facilitation of social activity in small groups,
- the relatively quick formation of a stable social order
- reduced aggression at feeding time,
- the provision of exercise and promoting of investigative behavior,
- the availability of bedding to facilitate rooting and chewing behavior,
- a more complex and stimulating environment,
- pulsative periods of direct contact with all of the boars in the barn, and
- controlled individual sow feeding without prolonged close confinement.

Information on the H-M system and the farrowing system described by Gadd is limited, especially with respect to pricing of the specialized equipment as the designs become available to commercial producers. For that reason, the economic analysis below is confined to a basic ESF system for gestating sows.

6.1 Electronic Sow Feeder System Description and Investment

Feed stations are strategically placed adjacent to pens and can serve up to 50 sows per station. One of the stations in the system is a separation station that can be programmed to direct preselected pigs to a holding area for treatment, pregnancy checks, or removal to the farrowing house. Sows have

24 hour access to the station and receive feed in portions until their daily allotment is consumed. The feed stations are served by a flex auger feed delivery system. Stations can be equipped with water injection into the feed tray to ensure faster eating.

The gestation stalls included in the baseline systems are eliminated under the ESF system. Building area per sow is increased to allow the sows more freedom of movement as well as to allow for room for the feed stations themselves. In research at the Research Institute for Pig Husbandry in the Netherlands, 80 sows are being housed in a building of 1,728 square feet, including 22 square feet for two feed stations. This is the same area per sow as assumed in the baseline gestation stall system when alleys are considered.

The investment required for gestation facilities under the ESF system are provided in Table 6.1. A printer for the computer and a water injection system are other equipment options that were not included here. The sows must be housed in rather large groups for efficient access to the feeders, so there do not appear to be clear guidelines at this point on placement of pen partitions. To arrive at a cost for pen partitions, the 6,688 square feet required for the 304 gestating sows in the large operation were assumed to be in a building approximately 50 by 135 feet. This building was divided into four pens with a partial wall within each pen to allow sows some escape from other aggressive sows. Three 50 foot walls and four 42 foot partitions are assumed, for 318 lineal feet of partition. This is one foot of partition per 21 square feet of building area.

A switch to ESF does not appear to make much difference in investment requirements. The gestation equipment cost for the smaller operation is greater than in the baseline ($23,166 compared to $18,716) but cheaper in the larger operation ($57,882 compared to $61,502) (Table 6.2). Building and equipment investment totals $3,518 and $2,763 per sow and total investment $4,127 and $3,313 per sow for the two sizes. Total investment is then 0.9 percent higher for the small operation and 0.2 percent lower for the large one. The decrease in the large operation and the increase in the small one occurs because of the fixed investment in a computer, transformer and separation station that is required regardless of size. In the baseline system, the gestation stalls made up a large share of the equipment cost, and their cost was a linear function of size. The ESF appears to contribute to economies of size in the operation[4].

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[4]Backus includes investment for the two systems in the Netherlands. He shows a slightly lower investment for the ESF system, instead of the greater investment shown here. The main difference between the two analyses appears to be that they allow 22 square feet per sow in both systems, instead of the 16 square feet assumed here. This analysis assumes a gestation stall 2 feet by 7 feet, with alleys kept to a minimum based on a Midwest Plan Service plan, to arrive at the 16 foot figure. Another difference is that the transponders are priced at about $30 in the Netherlands compared to the $41 quoted by a U.S. manufacturing representative. The difference may be related to the fact that the transponders are manufactured in the Netherlands. The gestation stalls are priced at $137 in the Netherlands compared to $100 for Minnesota, apparently because of higher steel prices there. All three of these factors tend to favor the ESF system in the Netherlands more than in Minnesota.

Table 6.1. Equipment Investment for Gestation Facilities in Electronic Sow Feeder System

Item	Small	Large
Walk-Through Feeding Stations[a] @ $2,695	(2) $5,390	(7) $18,865
Separation Feeding Station	4,008	4,008
Transponder (with ID number) @ $41	(98) 4,018	(322) 13,202
Computer[b]	5,000	5,000
Power Transformer, 24 Volt	1,000	1,000
Pen Partitions	1,697	7,166
Ventilation Equipment	756	3,192
Feed Storage and Delivery	1,009	4,233
Waterers	288	1,216
Total Equipment	23,166	57,882
Per Sow Place	$236	$180

[a]Capable of feeding 40 to 50 sows per station
[b]Price of computer will vary depending upon size of herd and purchaser discretion.

Source: Universal Dairy Equipment, Kansas City, Missouri

6.2 Electronic Sow Feeder System Sow Performance

Researchers appear to disagree about whether sow productivity with this system is expected to increase. Providing exercise for the dry sow can improve her muscle tone and make her more adept in handling herself once she enters the farrowing stall. Her movements might be more controlled and less sudden. As such, she is expected to crush fewer pigs (Morris and Hurnik). In a comparison between computerized feeding, confinement and interval feeding for dry sows, Singleton (1989) found computer feeding appeared to surpass the other systems in litter performance. The number of litters in the experiment was too limited, however, for the results to be statistically significant. On the other hand, Clanton found that fighting and stress reduces pigs born alive in group housing situations. Preliminary results from research in the Netherlands seem to agree with Clanton, finding about one less pig weaned per litter with ESF than with gestation stalls. Hoof lesions are more of a problem with group housing and ESF than with stalls in that research. Improved floor slat design may alleviate the hoof problems (Backus, personal communication). In light of these results, it seems prudent to assume comparable performance for ESF and the baseline until more definitive results are available.

Feed use with this system is expected to be similar to the precision type of feeding found in modern confinement. Literature provided by the manufacturer of the feeding system used in this analysis indicates a ninety eight percent accuracy through specific feed dosing. Singleton (1989) recorded improved feed efficiency and average daily gain for the sows in the computer feeding group over both the interval feeding system and the stall system. The interval feeding system showed the greatest deficiencies. Lactation weight loss was greatest for the sows within the computer feeding group. The ability to adjust feed intake at specific stages of the gestation by use of the computer would appear to be a benefit of the system. Gestation feed efficiency improvements are not incorporated in the results shown below. If Singleton's results on feed efficiency were incorporated, overall herd feed efficiency would improve slightly but gestation feed is such a small proportion of the total that the impact on profitability would be slight.

6.3 Electronic Sow Feeder System Labor Requirements

Labor requirements for the electronic sow feeding alternative are higher than for the baseline. Training new sows and gilts to use the system takes time as well as a high degree of patience (Miller, 1989). Netherlands research does not show this to add significantly to total labor requirements, however (Backus, personal communication). The replacement of lost collars is also time consuming in that design, but the problem is apparently lessened with the ear tag transponders and may be eliminated entirely with the subcutaneous design (Backus; Backus, personal communication). Although pigs that have learned the system seem to remember it for their lifetimes, dynamic individuals can be a problem (Clanton). Time-motion studies in the Netherlands suggest an overall increase in gestation labor of roughly 63 percent with ESF compared to gestation stalls (calculated from appendix tables in Backus). For this analysis, gestation labor for the small and large operations is increased by this percentage. Because the gestation facility accounts for only five percent of total labor in the swine operation, the increase in overall labor requirement is only three percent. The Netherlands research also shows that catching and handling sows in the ESF group housing situation is somewhat more difficult than when the sows are in stalls or tethers. No attempt has been made here to assign an economic cost to this added difficulty.

6.4 Electronic Sow Feeder System Economic Costs and Returns

Table 6.2 compares the costs with an electronic sow feeder-equipped gestation facility and with the baseline, gestation stall system. The comparison focuses on equipment fire and wind insurance, property taxes, repairs, depreciation, interest and labor, because the building itself is assumed the same for both systems. The annual feed, operating and ownership cost for the ESF system is estimated at $49.17 per hundredweight for the small operation and $45.03 for the large one, assuming an eight year life on the equipment with a six percent interest charge on average investment. The ESF system increases total cost per hundredweight by $0.29 and $0.09, assuming comparable sow productivity.

It should be noted that the ESF may be more easily adapted to a cheaper existing facility with solid floors than are gestation stalls. That advantage is not reflected in this analysis because new facilities are assumed throughout.

Table 6.2. Average Annual Cost With the Electronic Sow Feeder System

Item	Small	Large
Feed Costs	$135,377	$596,757
Operating	65,358	276,018
Equipment Ownership	53,485	178,265
Labor	28,420	93,794
Total Feed, Operating, Ownership and Labor Costs	$282,640	$1,144,835
Per Litter	$1,028	$941
Per Hundredweight of Pork	$49.17	$45.03

7. Straw Bedding System

The use of straw in intensive swine operations in the United States has been virtually eliminated, for several reasons. Cost and availability of straw is one reason. Cleanliness of the hog in a properly constructed liquid manure facility is another. The main reason would appear to be an overall acceptance of liquid manure systems as labor efficient and consistent with desired ground application techniques.

Animal welfare recommendations and regulations in Europe consistently list access to straw as a welfare consideration. The use of any sort of bedding is often considered as beneficial in eliminating abnormal (stereotypical) behavior and injury. Frazer (1975) states that sows with access to straw laid down more and were less apt to perform oral and other stereotypical behaviors. He goes on to say that sows without straw often appear motionless and drowsy while such appearances are eliminated through the use of straw.

It would be the best of both worlds if straw could be utilized in a liquid manure system. Certain pump/agitator manufacturers advertise their products as being able to handle manure with straw in it and with the consistency of a thick slurry, through a high speed chopper that reduces straw to mush before it reaches the pump. It is not recommended, however, that straw be utilized in liquid manure systems (Swine Housing and Equipment Handbook). Any fibrous material will interfere with agitation and pumping. Straw will also act to plug ports that release manure to central storage or provide access to the pump. In lagoon storage systems, straw will retard biological activity and require greater sludge capacity (Livestock Waste Facilities Handbook). Even in those instances where there is a physical separation of a bedded loafing area from a slatted dunging area, the hog will transport enough straw to the slats to disrupt the system (Larry Jacobson, personal communication). It might be surmised that some sort of chopping or shredding of the straw into fine enough material as not to foul the system would be a solution. The problem then becomes that as the bedding is reduced to bits and pieces, it becomes less and less appealing to the hog for chewing and rooting.

Straw is more commonly advocated for the breeding herd than for market animals. In gestation, it relieves long periods of confinement that might become boring. In the farrowing pen, straw allows expression of nesting instincts. Straw might also help prevent fighting in group pens (Fox). However, it is a poorer quality bedding than either wood shavings or ground corn cobs for absorption and hygiene.

Another area of concern with the gestation system analyzed here is the environmental hazard associated with runoff from dry lots and outdoor runs. Variations in lot size, site, soil type, annual precipitation and other factors including local regulations dictate the system and costs that would need to be considered (Pork Industry Handbook PIH-21). Ideally, and in some states by law, such facilities would be sited and constructed in such a way as to direct runoff of solids to a stage one settling basin with liquids going on to a holding pond or a vegetative infiltration area. The costs of maintaining strict environmental runoff controls would vary from site to site and were not considered here. The omission of such costs would only be of significance if factors dictated the need for such a system to be quite elaborate.

Parasites are a concern in a straw system with solid manure and group housing. Internal parasites may increase because of access to worm infested manure, while hog to hog transmission may increase external ones (Hawton, personal communication, Davis et al.). For this reason a more vigorous parasite control program is anticipated than in the baseline. Also, any time a manure pack is allowed to stand in excess of a week, flies will be a greater aggravation (Campbell et al.). Flies, while a nuisance, have little direct economic impact and no adjustment in operating costs was made. However, for operations near residential areas, flies moving off the farm could generate nuisance complaints that could create legal problems and costs not considered in this analysis.

7.1 Straw Bedding System Facility Scheduling, Sizing and Efficiency

The gestation, breeding and farrowing phases utilize straw in this system. The farrowing house is divided into rooms in much the same way as the baseline farrowing house. Instead of farrowing stalls over partial slats, however, each room contains individual farrowing pens. The gestation and breeding facilities in the straw system consist of "Cargill" monosloped structures, open to the south with solid concrete flooring. The gestation facility has an outside apron for dunging and exercise. The breeding facility is totally covered and designed for hand-mating, from Plan Number 6 in Levis but with the pens increased in area because of the solid floors.

Litter performance in such a system is expected to be adversely affected when compared to the baseline stall system. The freedom of movement offered to the sow both during parturition and postpartum might cause a reduction of one pig weaned per litter due to crushing (Hawton, personal communication). Therefore, in this analysis, eight pigs are weaned per litter versus the nine in the baseline system. Days to weaning and the other parameters used to schedule and size the system are the same as for the baseline system. The small and large operations are 120 and 505 sows, as in the baseline. However, pigs weaned are reduced by seven percent to 2,200 and 9,750, reducing the finishing capacity needed.

The lost revenues from crushing losses may be at least partially offset by reduced sow culling and replacement costs because of improved condition of the breeding herd. A recent Minnesota study of a straw bedded system with pen farrowing and group pens for gestation showed only one sow culled out of 20 over three parities, while six sows were culled from 20 housed in a conventional facility (Pijoan et al.; Pijoan, personal communication). An outbreak of swine mystery disease complicates use of this data. Also, over a longer time period with older sows and some culling for genetic improvement the difference in overall sow and boar culling rates may not be as great as these figures suggest but still may be significant. It might be reasonable to expect culling and death rates of half the baseline level, or 12.5 percent compared to 25 (Arellano, personal communication).

7.2 Straw Bedding System Growth and Feeding Performance

Feed consumption by the lactating sow in the straw system is reduced by one pound per day to 12 pounds to reflect the reduction in suckling piglets. Feed consumption by sows in breeding and gestation, and by the boars and gilt pool, is estimated to be eight percent higher with the straw system than in the baseline due to cold weather feeding. Whole-herd feed efficiency then worsens to 3.72 and 3.69 pounds of feed per pound of pork for the small and large systems. The decline is 0.12 for the small system and 0.11 for the large one.

7.3 Straw Bedding System Description and Investment

The farrowing pens measure five feet by eleven feet, with wood (sides) and steel pipe (ends) construction, with side protective rails and a corner creep area with a hover. It is estimated that such a pen could be constructed for $150. A solid floor with a rear gutter and barn cleaner is assumed. The building is priced as new construction, although such a system could be adapted to a remodeled dairy barn or another existing structure. As in the baseline system, feed is hand fed by cart from outside storage. A nipple waterer is provided. Ventilation, insulation and supplemental heat are provided at the same initial cost as in the baseline. However, the use of straw reduces fuel use and cost. The amount of the reduction is based on calculations from Mechanical Ventilating Systems for Livestock Housing MWPS-32). A thick bed of straw is said to lower the critical temperature for sow and litter in the farrowing barn by as much as ten to fifteen degrees, allowing for maintenance of lower indoor temperatures (Hawton and Jacobson, personal communication). Space requirements for the breeding herd are shown in Table 7.1. Building and equipment prices are summarized in Table 7.2.

The "Cargill" monoslope roofed gestation building is 16 feet deep with a 30 foot outside concrete apron serving as a run, dunging, feeding, and watering area. The shed and runs are divided every 10 feet into pens to hold up to 20 sows per pen at 8 square feet per sow inside the building and 14 square feet outside, with 5 and 16 pens for the small and large sizes, respectively. This facility uses straw bedding, but no supplemental heat or mechanical ventilation.

The breeding facility has boar pens, breeding pens and pens for sows that are newly weaned or being heat checked. The building is 23 by 106 feet for the small operation and 46 by 154 feet for the large one. This gives roughly 50 square feet for each sow and boar in the small system and 50 and 48 square feet for the boars and sows, respectively, in the large one.

It was assumed that the manager would utilize his own equipment in handling the solid manure, so a spreader and loader was added to the investment in miscellaneous equipment. A solid manure storage area was also added to hold six months' production of solid manure from the farrowing, breeding and gestation buildings. For the small operation, roughly 100 cubic feet of manure and bedding is produced per day. A concrete pad 45 by 50 feet with manure stacked an average of eight feet high will hold the 18,000 cubic feet required. The concrete cost was estimated assuming a four inch thickness for the pad priced at $42 per cubic yard. A pressure-treated wooden wall eight feet high with posts every eight feet was estimated at $5.61 per running foot. While a detailed layout of the buildings was not developed, it was assumed that a manure stacker would be needed to move the manure into the storage area. Few of these stackers are currently sold due to the shift to liquid manure, but a dealer quoted a price of $5,000 for a 32 foot stacker. The concrete and lumber cost $2,221, so the stacker is the most expensive part of the solid manure storage. For the large operation, a 90 by 100 foot area would be required, also with eight foot wooden walls, at $6,752. Two stackers were included for the large operation.

Table 7.1. Space Requirements, Straw System

	Building Area Per Pig	Capacity Required	
		Small	Large
	sq. ft.	head	head
Farrowing	70	32	120
Breeding			
Boars	50	9	25
Sows	50 small, 48 large	40	125
Gestation	8 inside, 14 outside	64	280
Gilt Pool	8 inside, 14 outside	17	21
Nursery	5.25	462	1,728
Grower	6.5	256	1,120
Finisher	8.7	384	1,920

Source: Building area per pig includes space for alleys and breeding pens based on building designs in the Swine Housing and Equipment Handbook and Levis.

Table 7.2. Prices Used for Breeding Herd Investment Calculations, Straw System

Item	Units	Stage: Farrowing	Stage: Gestation	Stage: Breeding
Capacity measured in units:		stall	sow or gilt	sow or boar
<u>Building</u>				
Shell:				
small	$foot^2$	$10.30	$8.64	$7.72
	head	721	71	386
large	$foot^2$	8.30	7.29	6.16
	head	581	58	298
<u>Equipment</u>, per head, both sizes[a]				
Stalls and pens[b]		150	23	139
Barn cleaner		181	0	0
Feed system		46	21	46
Water		20	6	20
Fans		37	0	0
Total Equipment		434	50	205

[a]See Table 3.4 footnotes for an explanation of the feed system and fan calculations.

[b]Breeding pen cost figures include grouped sow pens and individual boar pens with breeding pens factored in.

The nursery and growing/finishing facilities are the same as in the baseline and do not use straw, so the manure in those phases remains liquid. Because less liquid manure is being produced compared to the baseline, it was assumed to be pumped and spread by a custom applicator rather than owning liquid manure handling equipment.

Table 7.3 shows investment requirements for this system. Compared to the baseline investment, total dollars required is reduced by 20 percent for the small system to $3,234 per sow and 17 percent for the large to $2,747 due mainly to low investment type of structures utilized for farrowing and gestation facilities. Fewer market hogs on hand due to the reduction in pigs weaned per litter are also reflected in smaller nursery and growing/finishing facilities as well as reduced livestock inventory.

7.4 Straw Bedding System Labor Requirements

Labor requirements for such a system are expected to increase significantly in those phases where straw is utilized. McFate et al. provides an analysis of differences in labor requirements between a raised stall farrowing system and a solid manure system. Their estimate of a threefold increase in labor for the solid system was used for the breeding herd in this analysis (Table 7.4). For the small operation, total hours per sow is estimated at 48.4 compared to 23 in the baseline confinement system. For the large one, hours per sow are set at 38 versus 18 for the baseline. The solid manure system, the actual handling of the straw, and the increased difficulty of restraining the sow in the open instead of in a stall while performing normal care of the piglets contribute to the increase in labor with this system.

Labor in the straw system will depend on how often the operator desires to scrape the gestation facility outside run and the breeding facility pens. Feeding is expected to require more time as the gilts are hand-fed on the floor versus the semi-automated delivery system of the baseline system. Weather would play a part in how much labor would be required in such a system. A large snow fall would probably cause problems and increase attendant labor requirements. Worming of sows prior to transfer to farrowing would entail some additional labor. It is assumed that transfer of sows to farrowing would require more labor than would the baseline. Sows should also be washed, at least the udder area, when leaving such housing to go to farrowing.

On the other hand, Pijoan et al. found a 14 percent decrease in labor with a straw bedded system that included every other day gestation feeding and removable farrowing cubicles. The productivity loss they experienced was greater than assumed here, with a reduction of two pigs weaned per litter rather than one.

Labor for the nursery phase of the operation is reduced by 20 percent due to a lessor number of animals weaned per sow and the custom hiring of manure removal and application. Growing-finishing labor is reduced by 25 percent for the same reason.

Table 7.3. Investment Requirement for the Straw Bedding System

	Buildings	Equipment	Total	Per Pig Place
<u>Small</u>				
Land, 2.5 Acres			$2,500	
Facilities:				
Farrowing	$23,079	$13,888	$39,967	$1,155
Nursery	26,386	32,400	58,786	127
Growing-Finishing	76,786	20,736	97,522	152
Breeding	18,907	10,045	28,952	591
Gestation	6,941	4,900	11,841	120
Manure Storage:				
Solid	2,221	5,000	7,221	
Liquid	26,549	0	26,549	
Feed Mill and Grain Storage	17,723	18,500	36,223	
Miscellaneous Equipment	0	17,785	17,785	
Total Facilities	$198,592	$123,254	$321,846	
Per Sow	$1,655	$1,027	$2,682	
Livestock:				
Sows (120 head @ $250)			$30,000	
Gilt Pool (17 @ 250)			4,250	
Boars (9 @ 600)			5,400	
Market Animals (618 @ 39)			24,093	
Total Livestock (764)			$63,743	
Total Investment			$388,089	
Per Sow				$3,234
<u>Large</u>				
Land, 5.7 Acres			$5,700	
Facilities:				
Farrowing	$69,718	$52,080	$121,798	$1,015
Nursery	78,761	121,185	199,946	116
Growing-Finishing	317,620	98,496	416,116	137
Breeding	44,657	30,750	75,407	503
Gestation	18,785	16,100	34,885	108
Manure Storage:				
Solid	6,752	10,000	16,752	
Liquid	108,160	0	108,160	
Feed Mill and Grain Storage	77,742	55,000	132,742	
Miscellaneous Equipment	0	22,511	22,511	
Total Facilities	$722,196	$406,122	$1,128,318	
Per Sow	$1,430	$804	$2,234	
Livestock:				
Sows (505 head @ $250)			$126,250	
Gilt Pool (21 @ 250)			5,250	
Boars (25 @ 600)			15,000	
Market Animals (2,736 @ 39)			106,705	
Total Livestock (3,287)			$253,205	
Total Investment			$1,387,223	
Per Sow				$2,747

Table 7.4. Annual Labor Requirements by Stage and Size for the Straw Bedding System

	Small	Large
	hours per sow per year	
Stage		
Farrowing	27.55	21.61
Nursery	3.67	2.88
Growing-Finishing	3.44	2.70
Gestation/Breeding	13.78	10.80
Total	48.45	37.99

7.5 Straw Bedding System Economic Costs and Returns

Tables 7.5 and 7.6 show the annual costs and returns projected for the straw system. Straw requirements for this alternative are determined by assuming 35 pounds of straw (oat) are used per 100 pounds of moisture (Ensminger). In the farrowing barn, this works out to 11.3 pounds per day per litter. In the gestation building, three pounds per day per dry sow was the estimate. Straw is priced at $65 per ton, resulting in a bedding cost of $21 dollars per litter. Other changes in this alternative from the baseline system are in custom hiring of liquid manure pumping and spreading, and veterinary costs. Costs of custom hired manure pumping and application were set at $1.70 per litter, based on unpublished data from the Minnesota Farm Custom Rate Survey conducted in December, 1990 (see Lazarus and Fuller for a description of the survey). A $2.50 per litter cost of an injectable treatment that would control both internal and external parasites is included in veterinary and medicine costs, the same as in the northern outdoor system and half that assumed for the southern outdoor system.

The straw system as described above is not economically viable, due mainly to the increased labor requirements and the reduced litter size offsetting reduced ownership costs. Return to management and risk is $-9.13 for the small operation and $-3.80 for the large one. Operating costs per litter were up from the baseline, with the per litter cost of straw and parasite treatments more than offsetting the reduction in fuel and utilities.

In a sensitivity analysis of the large operation, increasing pigs weaned to nine per litter reduces the loss to $-0.80 per hundredweight. If some way were found to operate the system with the same labor requirement as the baseline but weaning eight pigs per litter, the operation achieves a return to management and risk of $1.08 per hundredweight. With both nine pigs weaned and no increase in labor, the return is $3.54 per hundredweight. On the other hand, halving the sow culling rate to 12.5 percent may be too optimistic. At the same 25 percent culling rate as the baseline, and with eight pigs per litter and three times the baseline labor, a loss of $-4.63 results.

8. Sow-Pig Nursery System

The practice of early weaning has gained wide acceptance as a means of enhancing scheduling and farrowing stall efficiency. It moves sows quickly from the farrowing stall into the breeding barn and allows the sow to be bred back sooner than would be the case with later weaning. The result is often more litters per year per sow and reduced farrowing stall requirements for the sow herd (Connor; Miller, 1990). Yet the practice does raise welfare concerns. Early weaning is said to unduly stress piglets. Producers practicing early weaning often admit that increased management is required to smooth out a stressful transition. While there is some argument that the practice of early weaning actually sets back a weaner to the point that overall gain and days to market are adversely affected (Cosic), in most instances, striving for a 21 day weaning age is said to give the producer the most production (Hays et al.) and reduced ownership costs per unit of production (Parker). However, some European policymakers have responded to the concerns about piglet stress by proposing restrictions on early weaning (Sharry).

8.1 Sow-Pig Nursery System Description

One practice that could alleviate some of the welfare concerns of early weaning without increasing the number of farrowing stalls needed is to transfer a sow and her litter from the farrowing barn, at one week to ten days postpartum, to a pen in a sow-pig nursery. This alternative allows the sow and piglets to remain together for an extended amount of time (five weeks assumed here) and then, after sow removal, adequate space is available for weaned pigs to remain in that same pen until transfer to the grower facility.

Table 7.5. Average Annual Costs and Returns, Small Straw Bedding System

	Per Litter	Per Cwt. of Pork	Total Per Year
Value Produced			
Market hogs - 7.528, 240 lbs. @ $46	$834.42	$45.36	$229,297
Cull sows and gilts - 0.11, 450 lbs. @ $38	19.47	1.06	5,351
Cull boars - 0.009, 450 lbs. @ $36.50	1.54	0.08	423
Total, 18.40 cwt.	$855.43	$46.50	$235,071
Feed Requirements and Costs			
Corn, 99 bu. @ $2.40	$236.65	$12.86	$65,030
Supplement, 0.66 ton @ $320	210.72	11.45	57,906
Total Feed	$447.37	$24.32	$122,936
Operating Costs			
Replacement boars	$5.63	$0.31	$1,546
Replacement gilts	31.25	1.70	8,588
Veterinary and medicine	33.50	1.82	9,206
Utilities, fuel and oil	27.50	1.49	7,557
Repairs	35.00	1.90	9,618
Straw	21.00	1.14	5,771
Custom Hire	1.70	0.09	467
Insurance and property taxes	22.95	1.25	6,307
Other	32.00	1.74	8,793
Total Operating	$210.53	$11.44	$57,853
Total Feed and Operating	$657.89	$35.76	$180,789
Return to Facility Investment, Labor, Management and Risk	$197.53	$10.74	$54,282
Facility Ownership Costs	153.84	8.36	42,276
Labor, 5,814 hrs. @ $10.00:	$211.56	$11.50	$58,135
Total Listed Costs	$1,023.29	$55.63	$281,201
Return to Management and Risk	$-167.87	$-9.13	$-46,130

Table 7.6. Average Annual Costs and Returns, Large Straw Bedding System

	Per Litter	Per Cwt. of Pork	Total Per Year
Value Produced			
Market hogs - 7.528, 241 lbs. @ $46	$834.42	$45.54	$1,015,525
Cull sows and gilts - 0.11, 450 lbs. @ $38	19.18	1.04	23,337
Cull boars - 0.006, 450 lbs. @ 36.50	1.02	0.06	1,237
Total, 18.38 cwt.	$854.61	$46.49	$1,040,100
Feed Requirements and Costs			
Corn, 98 bu. @ $2.40	$234.39	$12.75	$285,261
Supplement, 0.656 ton @ $320	210.03	11.43	255,614
Total Feed	$444.41	$24.18	$540,875
Operating Costs			
Replacement boars	$3.71	$0.20	$4,519
Replacement gilts	31.25	1.70	38,033
Veterinary and medicine	33.50	1.82	40,771
Utilities, fuel and oil	24.00	1.31	29,209
Repairs	35.00	1.90	42,597
Straw	21.00	1.14	25,558
Custom hire	1.70	0.09	2,069
Insurance and property taxes	18.37	1.00	22,363
Other	32.00	1.75	38,946
Total Operating	$200.54	$10.91	$244,064
Total Feed and Operating	$644.95	$35.09	$784,938
Return to Facility Investment, Labor, Management and Risk	$209.65	$11.41	$255,161
Facility Ownership Costs	$121.85	$6.63	$148,295
Labor, 19,186 hrs. @ $10.00:	$157.65	$8.58	$191,863
Total Listed Costs	$924.45	$50.29	$1,125,097
Return to Management and Risk	$-69.84	$-3.80	$-84,998

The design of the sow-pig nursery examined here is taken from the Midwest Planning Service Swine Housing and Equipment Handbook. Each pen would contain two sows and their litters. Although such a pen might often have solid flooring with bedding, this analysis will consider a slatted floor with a shallow pit scraper to central storage. A common practice when the pigs are first placed into the nursery is to place a solid platform over part of the slats and to provide space heating for the litters. With proper spacing of slats, piglets should have no trouble navigating the pen (Larry Jacobson, personal communication). Although it is anticipated the mean temperature in such a facility would be slightly lower than in a conventional nursery, the performance of the piglets should not be adversely affected (McCracken et al.).

The configuration of the insulated building used as the sow-pig nursery in this analysis for the small operation has eight rooms with four pens per room. The large operation requires 14 rooms, each containing eight pens to serve the schedule. The partially slatted pens are 8 feet by 10.5 feet giving each pig in excess of four square feet of floor space. Building area per pig is the same 5.25 square feet as assumed for the baseline nursery (Table 8.1). The sows are hand fed. The pigs are shifted from a nursery ration to a starter when the sow is removed. The feed is delivered through a flex auger system similar in style and price to the baseline system. Nipple waterers are utilized. Supplemental radiant heat is provided and priced in the same way as that in the conventional nursery.

The sow-pig nursery building has a stronger floor than the baseline nursery to support the sows, which increases the cost by about $5 per pig (Table 8.2). This is more than offset by fewer partitions, feeders and waterers because of combining two litters per pen, which reduces equipment costs by $16 per pig. The farrowing, breeding, gestation and growing/finishing facilities are the same as in the baseline. The buildings are slightly more expensive per square foot than the baseline because of their smaller sizes.

Table 8.1. Space Requirements, Sow-Pig Nursery System

	Capacity Required	
	Small	Large
	head	head
Farrowing	8	32
Breeding		
Boars	8	23
Sows	39	120
Gestation	70	224
Gilt Pool	21	34
Nursery	544	1,904
Grower	204	952
Finisher	408	1,768

8.2 Sow-Pig Nursery System Scheduling, Sizing and Efficiency

Table 8.3 lists the assumptions used in facility sizing and scheduling of the sow-pig nursery system. Weaning age was set at 36 days to allow for a schedule of nine days in the farrowing room and 27 days in the nursery. This is a delay of eight days for the small operation and 12 days in the large one. Days for rebreeding were shortened to four from eight or nine in the baseline. Evidence suggests that sows may cycle into heat sooner after weaning when weaning is delayed as in this system (Hawton, personal communication). Increased mortality in the nursery is expected to lower pigs weaned per litter by 0.5. These facilities will handle slightly fewer sows than the baseline - 110 sows instead of 120 for the small and 456 compared to 505 in the large operation. Labor per litter is assumed to be slightly higher, so that total labor requirements remain about the same as shown below. The number of farrowing stalls required is approximately one-quarter the number in the baseline systems. The later weaning age and the 0.5 pig increased pre-weaning mortality reduces pigs weaned per sow per year by 8 and 12 percent for the small and large operations, respectively.

Table 8.2. Prices Used for Investment Calculations, Sow-Pig Nursery System

Item	Units	Stage: Far-rowing	Nur-sery	Growing/ Finishing	Gesta-tion	Breed-ing
Capacity measured in units:		stall	pig	hog	sow or gilt	sow or boar
Building						
Shell:						
small	$foot^2$	$24.81	$12.09	$16.63	$17.06	$18.75
	head	1,588	63.48	132.52	375	629
large	$foot^2$	20.93	9.65	13.24	14.55	15.16
	head	1,340	50.66	105.02	145	499
Equipment, per head, both sizes[a]						
Stalls and pens		260	32.67	16.15	100	200
Feed system		40	13.80	12.69	60	46
Water		20	3.40	2.80	20	20
Fans		44	4.00	0.00	11	22
Total Equipment		364	53.87	32.40	191	288

[a]See Table 3.4 footnotes for an explanation of the stall, feed system and fan calculations.

Table 8.3. Facility Scheduling and Sizing Parameters and Resulting Size and Efficiency Estimates, Sow-Pig Nursery Systems

	Small	Large
Input Parameters		
Average Age of Pigs at Weaning	36	36
Number of Days to be Used for Rebreeding	4	4
Number of Pigs Weaned Per Litter	8.5	8.5
Number of Farrowing Rooms	1	2
Farrowing Stalls Per Room	8	16
Results		
Pigs Weaned Per Year	2,095	8,720
Number of Sows in the Herd (not including gilts past market weight but not yet bred)	110	456
Litters Per Year	246	1,026
Litters Per Mated Female Per Year	2.24	2.25
Pigs Weaned Per Mated Female Per Year	19.0	19.1
Actual Days Farrowing and Nursery Rooms Idle for Cleaning and Repair	5	4

8.3 Sow-Pig Nursery System Growth and Feeding Performance

The sows are on lactation feed longer, and lose more weight that must be replaced in gestation (Table 8.4). Nursery feed is reduced because the pigs are heavier at weaning. The nursery feed figures assume that some creep feed is provided but that feed consumption is not significant until weaning. Whole-herd feed efficiency declines by a fairly insignificant 0.05 pounds of feed per pound of pork as the breeding herd feed is allocated over slightly fewer market animals.

8.4 Sow-Pig Nursery System Investment

Table 8.5 shows the investment required for the sow-pig nursery system. Investment is reduced by roughly five percent for the small system to $3,868 per sow, due mainly to the reduced size of the farrowing building offset to some degree by the increased size of the nursery building. The other buildings are also reduced slightly in size with the reduced number of sows. The large system investment is also reduced by ten percent, to $2,971 per sow.

8.5 Sow-Pig Nursery System Labor Requirements

Labor for the farrowing and nursery stages was increased five percent to allow for the extra time to move sows from the farrowing room to the nursery (Table 8.6). Some time was also shifted from farrowing to nursery within that overall increase. Labor per pig was kept the same for the other stages, but the reduced litter size reduces finishing labor enough to offset the increased time in the nursery.

Table 8.4. Growth and Feeding Performance, Sow-Pig Nursery Systems

	Stage				
Breeding Herd	Breeding				Gilt
	Sow/Gilt	Boar	Gestation	Lactation	Pool
Period Considered	Litter	Year	Litter	Litter	Repl.
Total Days In Period	13	365	117	40	30
Lbs. Gain Per Animal	10	0	85	0	0
Feed Lbs. Per Day	5.2	7	5.5	13	5.5
Total Feed/Animal	68	2,555	644	520	165

Calculated whole-herd feed efficiency,
feed pounds per pound of pork 3.64

Table 8.5. Investment Requirement for the Sow-Pig Nursery System

	Buildings	Equipment	Total	Per Pig Place
Small				
Land, 2.5 Acres			$2,500	
Facilities:				
Farrowing	($12,701,	$2,912)	$15,613	$1,952
Nursery	(34,534,	29,305)	63,839	117
Growing-Finishing	(81,103,	19,829)	100,932	165
Breeding	(29,580,	13,536)	43,116	917
Gestation	(34,151,	17,381)	51,532	566
Manure Storage	(34,349,	0)	34,349	
Feed Mill and Grain Storage	(16,796,	18,500)	35,296	
Miscellaneous Equipment	(0,	17,785)	17,785	
Total Facilities	($243,213,	$119,248)	$362,461	
Per Sow	($2,211,	$1,084)	$3,295	
Livestock:				
Sows (110 head @ $250)			$27,500	
Boars (8 @ 600)			4,800	
Gilt Pool (21 @ 250)			5,250	
Market Animals (589 @ 39)			22,953	
Total Livestock (728)			$60,503	
Total Investment			$405,343	
Per Sow				$3,868
Large				
Land, 5.7 Acres			$5,700	
Facilities:				
Farrowing	($42,865,	$11,648)	$54,513	$1,703
Nursery	(96,461,	102,568)	199,030	104
Growing-Finishing	(285,658,	88,128)	373,786	137
Breeding	(71,399,	41,184)	112,583	787
Gestation	(82,611,	49,278)	131,889	511
Manure Storage	(98,319,	0)	98,319	
Feed Mill and Grain Storage	(69,685,	55,000)	124,685	
Miscellaneous Equipment	(0,	22,511)	22,511	
Total Facilities	($746,998,	$370,317)	$1,117,315	
Per Sow	($1,638,	$812)	$2,450	
Livestock:				
Sows (456 head @ $250)			$114,000	
Boars (23 @ 600)			13,800	
Gilt Pool (34 @ 250)			8,500	
Market Animals (2,451 @ 39)			95,577	
Total Livestock (2,964)			$231,877	
Total Investment			$1,354,893	
Per Sow				$2,971

Table 8.6. Annual Labor Requirements by Stage and Size for the Sow-Pig Nursery System

	Small	Large
	hours per sow per year	
Stage		
Farrowing	3.03	2.65
Nursery	11.12	7.94
Growing-Finishing	4.24	3.18
Breeding	3.37	2.52
Gestation	1.12	0.84
Total	22.88	17.13

8.6 Sow-Pig Nursery System Economic Costs and Returns

Return to management and risk declines by $1.39 to $-3.39 per hundredweight for the small operation, and drops $1.13 to $0.80 for the large one, compared to the baseline (Tables 8.6 and 8.7). The declines are due mainly to higher costs that are divided about equally among the feed, operating and labor costs with a lesser increase in ownership costs. Operating costs per litter were held constant, so that costs per hundredweight increased slightly with the reduced litter size.

An increase in pigs weaned per litter to 9 instead of 8.5 would bring the return to management and risk in the large operation to $1.98, slightly higher than the baseline. This system may have an advantage of reduced nursery mortality because the pigs are not moved at weaning. If 8.5 pigs were weaned but the four percent mortality were reduced to one percent, 0.25 more pigs would reach the grower stage and returns would be $1.55 per hundredweight.

Table 8.7. Average Annual Costs and Returns, Small Sow-Pig Nursery System

	Per Litter	Per Cwt. of Pork	Total Per Year
Value Produced			
Market hogs - 8.00, 240 lbs. @ $46	$885.90	$44.87	$218,287
Cull sows and gilts - 0.22, 450 lbs. @ $38	38.02	1.93	9,367
Cull boars - 0.018, 450 lbs. @ $36.50	2.99	0.15	736
Total, 19.75 cwt.	$926.91	$46.94	$228,390
Feed Requirements and Costs			
Corn, 104 bu. @ $2.40	$250.11	$12.67	$61,628
Supplement, 0.688 ton @ $320	220.27	11.16	54,274
Total Feed	$470.38	$23.82	$115,902
Operating Costs			
Marketing	$12.75	$0.65	$3,142
Replacement boars	10.91	0.55	2,688
Replacement gilts	62.50	3.17	15,400
Insurance and property taxes	28.35	1.44	6,986
Other	121.00	6.12	29,814
Total Operating	$235.51	$11.93	$58,030
Total Feed and Operating	$705.89	$35.75	$173,932
Return to Facility Investment, Labor, Management and Risk	$221.02	$11.16	$54,459
Facility Ownership Costs	$185.77	$9.41	$45,774
Labor, 2,517 hrs. @ $10.00:	$102.16	$5.17	$25,172
Total Listed Costs	$993.82	$50.33	$244,877
Return to Management and Risk	$-66.91	$-3.39	$-16,487

Table 8.8. Average Annual Costs and Returns, Large Sow-Pig Nursery System

	Per Litter	Per Cwt. of Pork	Total Per Year
Value Produced			
Market hogs - 8.00, 240 lbs. @ $46	$885.90	$44.89	$908,938
Cull sows and gilts - 0.22, 450 lbs. @ $38	38.04	1.93	39,027
Cull boars - 0.013, 450 lbs. @ 36.50	2.07	0.10	2,125
Total, 19.67 cwt.	$926.01	$46.92	$950,090
Feed Requirements and Costs			
Corn, 104 bu. @ $2.40	$249.22	$12.63	$255,695
Supplement, 0.686 ton @ $320	219.52	11.12	225,224
Total Feed	$468.73	$23.75	$480,919
Operating Costs			
Marketing	$12.75	$0.65	$13,082
Replacement boars	7.57	0.38	7,763
Replacement gilts	62.50	3.17	64,125
Insurance and property taxes	21.40	1.08	21,957
Other	121.00	6.13	124,145
Total Operating	$225.22	$11.41	$231,072
Total Feed and Operating	$693.95	$35.16	$711,991
Return to Facility Investment, Labor, Management and Risk	$232.07	$11.76	$238,099
Facility Ownership Costs	$140.22	$7.11	$143,864
Labor, 7,810 hrs. @ $10.00:	$76.12	$3.86	$78,104
Total Listed Costs	$910.29	$46.13	$933,959
Return to Management and Risk	$15.72	$0.80	$16,131

9. Intact Boar System

Marketing male hogs as boars rather than barrows has the potential to improve feed efficiency. Boars gain faster and require less feed per pound of gain than gilts. On the other hand, gilts are more efficient in converting feed to pork than barrows (Brooks et al.).

The main drawback to the use of the intact male as a market hog is boar taint in the meat. The taint, which effects the sensory perceptions of both taste and smell, is due to high levels of two substances, androstenone and skatole, in the fat (Diestre et al). While present in all hogs including gilts, the chance of taint is far higher in the boar. The possibility of taint offers problems to an industry that relies upon consumer acceptance of its product.

Boar taint is considered more of a function of age than live weight (Hawton, personal communication). Genetics might also be an important factor, suggesting an early maturing hog with low genetic predispostion for boar taint might be developed over time to circumvent the problem of tainted meat (Epley, personal communication). The current method is to market hogs at a younger age and lower weight. The European experience seems to indicate an age of about five and a half months as the maximum that will avoid serious problems with taint (Meyer, personal communication). The trend in market weights in the United States has been to higher market weights, however, so the use of boars as market hogs certainly would require adjusting the marketing strategy and perhaps a restructuring of the entire sector.

It appears that the move toward "entires" in Europe has been made as much or more because of welfare concerns as for the economic advantages of utilization of the more efficient boar (Kempster et al.). Castration is considered a subjugation of farm animals to suit the taste of humans. In any case, the European experience, along with research done in the U.S. and Canada, provides a useful tool by which to judge the effect of such an alternative in the United States.

Consumer acceptance of boar meat is difficult to assess. On the one hand, the consumers seem to be searching for leaner meat. On the other hand, one would hardly expect the food preparer and household to accept a food buying decision that entailed the gamble of finding tainted meat every time purchased pork was cooked. Kempster et al. (1986) reported that a consumer study of meat taken from boars and gilts showed equal acceptability of eating quality. Clipleff et al. (1984) found similar results in consumer acceptance reporting no significant differences in organolyptic scores and only a slight preference for barrow meat because of higher fat content making the barrow meat more palatable. Boar taint was not a factor. Seideman et al. (1982) on the other hand found that flavor and odor were major disadvantages of boar meat. Diestre et al. (1990) states flatly that in Spain, any move toward utilization of boars as market hogs is "risky" due to tainted meat.

One means of eliminating the concern over boar taint is through the use of immunogens that would work to inhibit the formation of androstenone. Research indicates that the results of utilizing such immunogens, while far from perfect, offers optimism enough to influence further research (Brooks, Williamson et al).

Carcass quality and feed conversion information in most instances favor the boar over the barrow. Brooks et al. report an 8 to 10 percent increase in lean meat and a 12 to 15 percent advantage in feed conversion in favor of the boar over the barrow. Fortin (1983) reported feed conversion for the boar of 3.01, 12 percent higher than the 3.41 for the barrow. The boar carcass averaged 11.72 percent fat versus 13.02 percent in the barrow. Wood and Riley report significant advantage for the boar in daily growth and feed conversion.

Not all carcass traits favor the boar. Thicker skin makes joint separation more difficult for the processor. Dressing percentages are reduced because of less fat. Leaner meat with resulting higher water contents lower bacon yields from boar bellies (Wood and Enser). Despite more and leaner meat on the boar carcass, overall carcass value might not be significantly affected. Using pork wholesale carcass price calculations from the Live Animal Carcass Evaluation and Selection Manual and cut percentages from Fortin (1983) indicates no advantage in carcass value for the boar over the barrow (Table 9.1). This is due largely to the fact that much of the added lean meat found on the boar carcass is located in cheaper cuts. The slaughter weights for the 24 boars in the Fortin trial averaged 204 pounds with a dressing percentage of 81.9, with the same number of barrows averaging 203 pounds with a dressing percentage of 83.0.

Table 9.1. Comparison of Boar and Barrow Carcass Values[a]

		Boar		Barrow	
Primal Cut	Price Pound	Weight Carcass	Value Carcass	Weight Carcass	Value Carcass
	$/lb.	lbs.	$	lbs.	$
Slaughter weight		203.72		203.06	
Warm carcass weight		166.83		168.54	
Ham	0.92	36.88	33.93	36.82	33.88
Loin	1.03	48.58	50.04	50.88	52.41
Belly	0.61	28.29	17.26	29.51	18.00
Picnic	0.69	36.64	25.28	34.92	24.10
Jowl	0.46	7.27	3.34	6.82	3.14
Feet	0.24	5.42	1.30	5.07	1.22
Carcass Value - Total		163.09	131.16	164.04	132.74
Carcass Value Per Pound			0.80		0.81
Fat trimmed[b] (by subtraction)		3.74		4.50	

Sources: Primal cut prices from Boggs et al., weights for different cuts from Fortin et al.

[a]excludes: spareribs, neckbone, tail, and fat and lean trim; boston factored into picnic calculation.

[b]Ham, loin and the picnic and butt cuts trimmed to approximately 7 mm of fat.

9.1 Intact Boar System Growth and Feeding Performance

The change in overall herd feed efficiency from the baseline was calculated by considering the market boars and gilts separately, and assuming fifty percent of each. Gilts were assumed to be eight percent more efficient in feed per pound of gain than barrows in the finishing stage, or four percent more efficient than the barrow/gilt combination of the baseline litter in the growing and finishing phases, based on Knudson et al. Boars were assumed to have a 20 percent advantage over the barrow/gilt combination. Knudson et al. found that the advantage in feed efficiency became apparent after 100 pounds, so feed per pound of gain in the growing stage was also reduced by one-third of these amounts to account for the last 21 pounds before moving to the finishing stage at 121 pounds. A slight additional improvement in feed efficiency can be expected due to the lighter market weight of 210 pounds instead of 240, apart from the impact of non-castration. Feed per pound of gain was reduced by an additional three percent to adjust for this lighter market weight, based on Life Cycle Swine Nutrition. Overall herd feed efficiency improves to 3.27 pounds feed per pound of pork for the small operation (Table 9.2). The large operation achieved 3.25 because of the four day earlier weaning age than in the small operation, the same as in the baseline. Average daily gain was assumed to be the same as in the baseline.

Split-sex feeding is assumed for the finishing stage. The greater efficiency and higher proportion of lean meat requires a higher protein finishing ration. A finishing ration with 18 percent protein for the boars and 16 percent for gilts is used instead of the 15 percent baseline finishing ration. The higher protein levels increase the cost per ton of the feed somewhat, so that the improvement in feed efficiency does not translate into as great an advantage in feed cost. Feed cost is $22.24 per hundredweight of pork for the large operation compared to $23.47 for the baseline, a reduction of five percent. Dual feed bins and distribution augers are also required for split-sex feeding. These were estimated to add $3 per pig place to the growing/finishing $32.40 equipment cost.

investment

Table 9.2. Growth and Feeding Performance, Small Intact Boar System

		Stage			
	All	Gilts		Boars	
Market Animals	Nursery	Growing	Finishing	Growing	Finishing
Pigs/Litter	8.64	4.28	4.23	4.28	4.23
Ending Weight	56	121	209	121	209
Gain, Lbs. Per Pig	41	65	88	65	88
Ending Age	74	115	165	115	165
Days in Stage	46	41	50	41	50
Average Daily Gain	0.89	1.58	1.76	1.58	1.76
Feed Per Pig, Lbs.	76	175	328	175	273
Feed Per Lb. Gain	1.8	2.82	3.87	2.61	3.59
Corn Percent	69.75	77.9	80.0	77.9	77.9
Supplement Percent	30.25	22.1	20.0	22.1	22.1

Breeding Herd	Breeding				Gilt
	Sow/Gilt	Boar	Gestation	Lactation	Pool
Period Considered	Litter	Year	Litter	Litter	Repl.
Total Days In Period	15	365	117	31	36
Lbs. Gain Per Animal	10	0	76	0	0
Feed Lbs. Per Day	5.2	7.0	5.2	13.0	5.2
Total Feed/Animal	78	2,555	608	403	187

Calculated whole-herd feed efficiency,
feed pounds per pound of pork 3.27

9.2 Intact Boar System Growing/Finishing Facility Description and Investment

Due to uncertainty about the market age and weight at which boar taint could become noticeable, a sensitivity analysis of market weights from 180 through 240 pounds was performed. The analysis assumes that gilts and boars are marketed at the same weights to simplify scheduling. This is consistent with European practices where entires are common (Vern Meyer, personal communication). An operation marketing hogs at lighter weights requires less finishing space for two reasons: first, smaller hogs require less area per hog, and second, the shorter finishing time results in fewer hogs on the finishing floor at any one time. The area per pig was reduced in proportion to the reduction in market weight. At the daily gains shown in Table 9.2, the hogs reach a 210 pound market weight at 165 days, 18 days earlier than the baseline. Seideman et al. find that while feed per pound of gain is better for boars, rate of gain is about the same as for barrows.

The growing and finishing capacities required at each market weight are shown in Table 9.3, both as number of animals and square feet. Grower building area is calculated for the first 275 animals for the small operations and 1,204 animals for the large one at 6.5 square feet per animal, as in the baseline. Finishing space is allocated to the remaining animals based on the building areas per head shown. The 8.7 square feet for a 240 pound hog is based on 8.0 square feet pen area plus nine percent additional space for alleys.

Table 9.3. Growing and Finishing Space Requirements for the Intact Boar System, by Market Weight

Market Weight	Age at Market Weight	Head Capacity Small	Head Capacity Large	Finishing Area: Pen Area Per Head	Finishing Area: Total Building Small	Finishing Area: Total Building Large
lbs.	days	- - -head - - -		- - sq. ft. - -		
Baseline						
240	183	688	3,268	8.7	5,381	25,783
Boar system						
240	183	688	3,268	8.7	5,381	25,783
227	175	638	3,176	8.5	4,790	24,121
218	170	607	3,118	8.3	4,460	23,227
209	165	576	3,060	8.0	4,210	22,762
200	160	545	3,002	7.8	3,901	21,906
192	155	514	2,944	7.6	3,605	21,075
183	150	483	2,887	7.4	3,323	20,269

Table 9.4 shows the investment required for the intact boar system. The only difference from the baseline is in the size of the growing-finishing facility and the inventory of market animals resulting from the difference in market weights. Investment is reduced by roughly eight percent for the small system to $3,473 per sow. The large system investment is reduced by about six percent, to $3,025 per sow. Table 9.4 is based on marketing at 210 pounds, but calculations were also made for the range of weights from 183 to 240 for the sensitivity analysis of costs and returns.

9.3 Intact Boar System Labor Requirements

Little information is available on how much labor savings would result in the farrowing room due to eliminating the castration task. A savings of roughly four percent was assumed (Table 9.5). A 10 percent reduction in labor required for the growing-finishing animals was also assumed for the 210 pound market weight. This is less than the roughly 17 percent reduction in number of market animals on hand, allowing for the increased repair and maintenance labor required to feed the boars. Labor requirements remain the same for the other stages, for an overall labor savings of 3.4 percent.

9.4 Intact Boar System Market Price Penalty

The price received for market animals shipped at lighter weights is perhaps the greatest unknown in this system, given the uncertainties about consumer acceptance and processing costs. For the purpose of this study, the approach taken was a simplistic one because of the lack of data for a more detailed analysis. It was assumed that the wholesale (carcass) price of pork stays the same but that processing costs would increase because of killing and cutting operations that take about the same amount of time per animal regardless of weight. The farm-to-carcass price spread for pork averaged 31.9 cents per retail pound between 1980 and 1989 (Putnam). Assuming 1.7 pounds liveweight per pound retail gives a processing margin of 18.76 cents per hundredweight live.

Table 9.4. Investment Requirement for the Intact Boar System

	Buildings	Equipment	Total	Per Pig Place
Small				
Land, 2.5 Acres @ $1,000			$2,500	
Facilities:				
Farrowing	$42,865	$11,648	$54,513	$1,704
Nursery	28,270	34,714	62,985	127
Growing-Finishing	70,028	19,526	89,554	156
Breeding	31,679	14,112	45,791	935
Gestation	36,778	18,718	55,496	566
Manure Storage	20,681	0	20,681	
Feed Mill and Grain Storage	14,979	18,500	33,479	
Miscellaneous Equipment	0	17,785	17,785	
Total Facilities	$245,281	135,004	380,284	
Per Sow	$2,044	$1,125	$3,169	
Livestock:				
Sows (120 head @ $250)			$30,000	
Boars (9 @ 600)			5,400	
Gilt Pool (34 @ 250)			8,500	
Market Animals (580 @ 39)			22,629	
Total Livestock (743)			$66,529	
Total Investment				$449,313
Per Sow				$3,744
Large				
Land, 5.7 Acres			$5,700	
Facilities:				
Farrowing	$136,931	$43,680	$180,611	$1,505
Nursery	84,504	130,021	214,525	116
Growing-Finishing	301,439	103,734	405,173	132
Breeding	75,795	43,200	118,995	793
Gestation	96,452	61,502	157,954	490
Manure Storage	66,981	0	66,981	
Feed Mill and Grain Storage	65,681	55,000	120,681	
Miscellaneous Equipment	0	22,511	22,511	
Total Facilities	$827,785	$459,648	$1,287,433	
Per Sow	$1,639	$910	$2,549	
Livestock:				
Sows (505 head @ $250)			$126,250	
Boars (25 @ 600)			15,000	
Gilt Pool (42 @ 250)			10,500	
Market Animals (2,570 @ 39)			100,220	
Total Livestock (3,142)			$251,970	
Total Investment			$1,545,102	
Per Sow				$3,060

Table 9.5. Annual Labor Requirements by Stage and Size for the Intact Boar System

	Small	Large
	hours per sow per year	
<u>Stage</u>		
Farrowing	8.72	6.84
Nursery	4.59	3.60
Growing-Finishing	4.13	3.24
Breeding	3.45	2.70
Gestation	1.15	0.90
Total	22.05	17.28

For a 240 pound hog, then, the spread is \$0.1876 x 240 or \$45.02 per animal. If the entire \$45.02 were incurred as weight were to be reduced to, say, 210 pounds, the spread would increase to \$45.02 / 210 or \$0.2144 per pound, an increase of \$2.68 per hundredweight. Some of the slaughtering tasks would probably cost less at lighter weights, suggesting the margin would increase by one to two dollars per hundredweight.

The carcass to retail margin averaged \$36.67 per hundredweight live over the 1980-89 period. This margin might be expected to increase with lighter weights, but by a lesser amount because cutting tasks represent less of the total process. If 25 percent of the \$36.67 stayed constant on a per head basis, the increase would be another \$1.31. Summing the change in the farm to carcass spread and the carcass to retail spread suggests the farm price of market hogs might be expected to drop by two to three dollars per hundredweight with a shift from marketing at 240 to 210 pounds. A decrease of three dollars to \$43 per hundredweight was used as the most likely scenario, with a sensitivity analysis from \$40 to \$46 at the 210 pound weight. A sensitivity analysis was completed for varying market weights and assuming that the price penalty varies from zero at 240 pounds to six dollars at 180 pounds.

9.5 <u>Intact Boar System Economic Costs and Returns</u>

The intact boar system does not appear competitive with the baseline system. At the small size, returns to management and risk, which were \$-2.07 per hundredweight for the baseline system, decline to \$-6.26 (Table 9.6). Returns to management and risk for the large system, which were \$1.93 per hundredweight with the baseline system, fall \$3.99, to \$-2.06 (Table 9.7).

Looking at the large operation, feed cost drops \$1.23 per hundredweight of pork. The largest single factor hurting this system is a \$2.80 drop in the value received per hundred pounds of pork sold. Operating costs were assumed to remain about the same on a per litter basis except for insurance and taxes on the finishing facility, but they increase by \$1.50 on a hundredweight basis because of the reduced pounds sold. Ownership costs increase by $0.49 and labor by $0.36 as the breeding facilities and labor are spread over fewer pounds.

A sensitivity analysis was done on the market weights for the large operation in order to find those at which returns to management and risk are comparable to the baseline, which was $1.93 per hundredweight. It indicated that returns would be less than the baseline at any market weight below about 230, and would be positive above 220 pounds:

Market Weight	Price	Return to Management and Risk Per Hundredweight
183	$40.29	$-7.10
192	41.17	-5.32
200	42.05	-3.65
209	42.93	-2.06
218	43.81	-0.41
227	44.69	1.04
236	45.57	2.43

Table 9.6. Average Annual Costs and Returns, Small Intact Boar System

	Per Litter	Per Cwt. of Pork	Total Per Year
Value Produced			
Market hogs - 8.47, 209 lbs. @ $42.93	$760.85	$41.77	$209,062
Cull sows and gilts - 0.22, 450 lbs. @ $38	38.12	2.09	10,475
Cull boars - 0.019, 450 lbs. @ $36.50	3.08	0.17	846
Total, 18.21 cwt.	$802.05	$44.03	$220,404
Feed Requirements and Costs			
Corn, 83 bu. @ $2.40	$200.01	$10.98	$54,963
Supplement, 0.647 ton @ $320	207.16	11.37	56,928
Total Feed	407.17	22.35	111,891
Operating Costs			
Insurance and property taxes	26.77	1.47	7,358
Other	208.25	11.43	57,227
Total Operating	$235.02	$12.90	$64,585
Total Feed and Operating	$642.20	$35.26	$176,476
Return to Facility Investment, Labor, Management and Risk	$159.85	$8.78	$43,928
Facility Ownership Costs	$177.50	$9.75	$48,778
Labor, 2,646 hrs. @ $10.00:	$96.29	$5.29	$26,460
Total Listed Costs	$915.99	$50.29	$251,714
Return to Management and Risk	$-113.94	$-6.26	$-31,309

Table 9.7. Average Annual Costs and Returns, Large Intact Boar System

	Per Litter	Per Cwt. of Pork	Total Per Year
Value Produced			
Market hogs - 8.47, 209 lbs. @ $42.93	$760.85	$41.79	$925,996
Cull sows and gilts - 0.22, 450 lbs. @ $38	38.35	2.11	46,675
Cull boars - 0.012, 450 lbs. @ 36.50	2.03	0.11	2,474
Total, 18.21 cwt.	$801.24	$44.00	$975,145
Feed Requirements and Costs			
Corn, 83 bu. @ $2.40	$198.02	$10.88	$241,005
Supplement, 0.646 ton @ $320	206.84	11.36	251,735
Total Feed	404.86	22.24	492,740
Operating Costs			
Insurance and property taxes	20.65	1.13	25,135
Other	204.43	11.23	248,797
Total Operating	$225.08	$12.36	$273,932
Total Feed and Operating	$629.94	$34.60	$766,672
Return to Facility Investment, Labor, Management and Risk	$171.29	$9.41	$208,473
Facility Ownership Costs	$136.99	$7.52	$166,725
Labor, 8,729 hrs. @ $10.00:	$71.72	$3.94	$87,287
Total Listed Costs	$838.65	$46.06	$1,020,683
Return to Management and Risk	$-37.42	$-2.06	$-45,539

10. Summary and Conclusions

Public concern about animal welfare and animal rights appears to be increasing in the United States as the 1980's draw to a close and we enter the 1990's. The purpose of this study was to evaluate the economic impacts that potentially could occur in representative swine facilities from adopting production systems and equipment which address selected animal welfare concerns. This study is intended to provide guidance to policymakers and others evaluating the economic impacts of a selection of alternative production systems and equipment.

Specific welfare concerns addressed are stocking density, early weaning, gestation stalls, boredom and lack of environmental stimuli, castration, and access to the outdoors. The outdoor systems, the turnaround stall, electronic sow feeders, the straw bedding system, and the sow-pig nursery all provide different amounts of space to the breeding herd at different stages of production. To respond to the early weaning concern, this study provided a sow-pig nursery alternative which made for a more efficient use of farrowing stalls but still delayed the sows entry into the breeding facility. Electronic sow feeding systems and the turnaround stall system provide alternatives to the standard gestation stall in the gestating and breeding phase of production. A straw farrowing and gestating alternative system addresses concerns about boredom and lack of stimuli. An intact boar system is analyzed to address the castration issue.

The major alternative systems considered then were:

1. Extensive/outdoor breeding, gestation, farrowing and nursery,

2. The turnaround stall as a potential improvement on the conventional gestation stall,

3. Electronic sow feeders for use in group housing of gestating sows,

4. The sow-pig nursery, with farrowing in conventional farrowing stalls followed by movement to two-litter nursery pens at about one week of age,

5. A straw system with farrowing, breeding and gestation in a straw bedded, solid manure facility, and

6. An intact boar system, where boars are not castrated but are marketed at lighter weights to avoid boar odor.

A conventional farrow-to-finish system is considered the baseline for this study. Two operation sizes, 120 and 505 sows, were considered to at least partially address economies of size related to increasing size of buildings and manure storage area, volume and perimeter relationships.

10.1 Physical Performance

The baseline system is assumed to achieve 20.6 pigs weaned per mated female per year in the small operation and 21.7 pigs in the large one. Whole-herd feed efficiency is 3.60 and 3.58 pounds of feed per pound of gain, respectively, for the small and large operations. Pigs are weaned at 28 and 24 days, with 2.29 and 2.41 litters per mated female per year. Nine pigs are weaned per litter. Hybrid F1 replacement gilts as well as boars are purchased in the baseline and all of the alternatives except for an all-gilt, outdoor system. The all-gilt outdoor system raises its own replacement gilts.

An outdoor system was analyzed for the large size only, but for both a southern and northern U.S. location. Pigs weaned per litter were reduced by one pig to eight for this alternative in the southern location. Litters per year were also reduced to 2.34 from the baseline 2.41. For the northern one, gilts were kept from the market animals raised in the operation rather than purchasing F1 gilts. Because of reduced heterosis and the use of all gilts, weaned litter size was reduced further to 7.5 for the northern location. Feed efficiency was reduced to 3.66 for the southern location and 3.79 for the northern one. Weaned litter size was also reduced to eight in the straw bedding system because the sows farrow in straw-bedded pens instead of stalls. Feed efficiency in the straw bedding system falls to 3.72 and 3.69 for the two sizes because of spreading the breeding herd feed over fewer market animals. Feed cost per hundredweight of pork produced is estimated at $24.31 for the southern outdoor system and $24.71 for the northern outdoor one, versus the $23.47 of the large baseline confinement system. In an area where corn cost 40 cents more than the $2.40 used here, feed cost per hundredweight of pork produced would be $26.10, or $2.63 more than the baseline. For the sow-pig nursery system, 8.5 pigs are weaned resulting in a feed efficiency of 3.65 and 3.64 for the small and large operations.

Pigs weaned per litter for the turnaround stall, electronic sow feeder and intact boar systems were assumed the same as the baseline. Gestation feed was increased 10 percent over the baseline for the turnaround stall because gestating sows must be fed on the floor, to allow for increased wastage over that with a feed trough or feeder. Whole-herd feed efficiency is then 0.8 percent lower at 3.63 and 3.61 pounds for the small and large operations. In the intact boar system, feed efficiency is better for the market boars than for the baseline barrows. However, the market animals are sold at 210 pounds instead of the baseline 240 to reduce boar odor. The lighter market weight reduces pork pounds sold relative to the feed required for the breeding herd and so that whole-herd feed efficiency does not increase as much as one would think when considering only the finishing stage. The increase is to 3.27 and 3.25 for the small and large operations, nine percent better than the baseline.

Sow condition may be improved by systems that allow more freedom of movement, affecting cull rate and cost of replacement animals. A sow culling rate of 25 percent per litter is assumed for the baseline system and all of the alternative systems except for the straw bedded system with pen farrowing and group gestation pens, for which 12.5 percent is used.

10.2 Investment Requirements

A prime motivation for this study was to provide input into possible legislation at the state or federal level. Legislation requiring changes in the behavior of people or firms frequently "grandfathers in" existing operations and forces changes only when new facilities are constructed or existing ones remodelled, as in building and electrical codes. If animal welfare legislation were to take this route, which seems likely, then the appropriate baseline is the level of technology, performance, and size found in the state-of-the-art confinement systems being constructed today. That is, the new systems being built at the current time are the ones that will be affected by the legislation. Therefore, The baseline systems are environmentally controlled confinement systems with totally slatted floors in the finishing building. They were designed and priced for a climate similar to southern Minnesota. The buildings and equipment cost $3,481 and $2,770 per sow, respectively, for the 120 and 505 sow operations. Total investment with land and livestock is $4,090 and $3,320 per sow.

Total investment for a 500 sow system with the breeding herd housed entirely outdoors in huts and shelters in a southern state such as North Carolina is $2,381 per sow. In a northern location such as Minnesota, an all-gilt system farrowing outdoors in huts only in the summer months requires an investment of $1,750 per gilt.

Total investment with turnaround gestation stalls is $4,116 and $3,333 for the small and large operations, respectively. This is a slight increase over the baseline, 0.6 percent for the small operation and 0.4 percent for the large one. The stalls are currently priced higher than conventional stalls, partially offset by the elimination of some alleys because an alley is needed at only one end of the stall instead of both ends.

Total investment with gestation sow group housing and an electronic sow feeder is $4,127 and $3,313 per sow for the two sizes. This is 0.9 percent higher for the small operation and 0.2 percent lower for the large one. The difference is minor, but suggests that components such as the computer controller for the feeder, only one of which are required for either size operation, contribute slightly to economies of size with the larger operation.

The system with straw bedding and solid floors requires 20 percent less capital for the small system at $3,234 per sow and 17 percent less for the large to $2,747 due mainly to low investment type of structures utilized for farrowing and gestation facilities.

Investment in the sow-pig nursery system is reduced by roughly five percent for the small system to $3,868 per sow, due mainly to the reduced size of the farrowing building offset to some degree by the increased size of the nursery building. The other buildings are also reduced slightly in size with the reduced number of sows. The large system investment is reduced by about ten percent, to $2,971 per sow.

Intact boar system investment is reduced by roughly eight percent for the small system to $3,744 per sow, due to the reduced finishing area along with some reduction in the capacity of the feed handling facilities and fewer market animals. The large system investment is reduced to $3,060 per sow.

10.3 Labor Requirements

Labor requirements for the baseline system were set at 23 hours per sow per year for the smaller size and 18 hours for the larger system, based on farm survey data. In order to evaluate the impact of changes in facilities at different stages on total labor requirements, farrowing was assumed to require

40 percent of these totals. Labor in the nursery was allocated 20 percent, the breeding barn 15 percent, and gestation five percent. The remaining 20 percent is allocated to growing/finishing.

Labor per sow for the electronic sow feeder system was increased 63 percent in the gestating phase to account for extra time to identify and catch the loose sows for handling. Training new sows and gilts to use the system and handling them in the group housing situation requires a high degree of patience. Turnaround stall labor was also increased slightly for time to observe sows as they are introduced into the system. Because the gestation facility accounts for only five percent of total labor in the swine operation, the increase in overall labor requirement is slight. Sow-pig nursery system farrowing and nursery labor per litter is increased five percent over the baseline, but fewer litters per sow per year reduce the hours per year shown in the table below the baseline levels.

For the southern outdoor system where breeding, gestation and farrowing are all outside, labor for all three stages is increased 17 percent from the baseline to 19 hours per sow. Nursery and grow/finish hours per pig finished are the same as in the baseline. The result is a total labor per sow per year 4.8 percent higher than the baseline. In the northern all-gilt system, total labor hours per gilt per year are about half those for the baseline, but because fewer pigs are produced with summer farrowing only, labor hours and cost per hundredweight are higher.

Intact boar system labor requirements are reduced four percent because the hogs are marketed at a younger age. Straw bedding system labor requirements per sow per year were estimated at three times the baseline for the breeding herd or more than twice as much overall at 48 and 38 hours per sow in the small and large operations.

10.4 Costs and Returns Per Hundredweight

The small baseline operation shows a loss of $2.01 per hundredweight with interest on the facilities and livestock charged at six percent. The large operation shows a profit of $1.93 per hundredweight. Return over feed and operating expenses was used to calculate the size of construction loan that can be serviced in an average year with a seven year term at 12 percent. The maximum amount of the investment that can be financed out of cash flow in the average year is 38 percent for the small operation, and 62 percent for the large size.

In the southern outdoor system, return to management and risk is $-0.08 per hundredweight compared to the baseline $1.93. A 40 cents per bushel higher corn price would reduce returns to management and risk to $-2.19 per hundredweight. If the same weaned litter size could be achieved with the southern outdoor system as with the baseline, nine pigs per litter, return would also be comparable at $2.05. The $-3.33 per hundredweight loss in the northern outdoor system illustrates why outdoor systems are no longer used by many producers in Minnesota. If purchased feeder pigs are not available for finishing in the northern operation when raised pigs are not available, returns fall to $-6.21.

In the small operation with the turnaround stalls, the overall economic impact is a cost increase of $0.37 per hundredweight of pork. For the large operation, the increase in cost totals $0.32 per hundredweight. Most of this increased cost is because of the ten percent increase in wasted feed for the sows in breeding and gestation and for the gilt pool. Costs increase by only $0.10 for the large operation if feed consumption is assumed to be no more than in the baseline. The group housing-electronic sow feeder system increases cost per hundredweight by $0.28 and $0.09 for the small and large operations, assuming comparable sow productivity.

Return to management and risk is $-9.13 for the small straw bedded operation and $-3.80 for the large one. These are declines of $7.12 and $5.73 per hundredweight compared to the baseline for the small and large sizes, respectively. The declines are due mainly to a tripling in labor for the breeding herd. Operating costs per litter were also up from the baseline, with the per litter cost of straw and parasite treatments more than offsetting the reduction in fuel and utilities. In a sensitivity analysis of the large operation, increasing pigs weaned to nine per litter reduces the loss to $-0.80 per hundredweight. If some way were found to operate the system with the same labor requirement as the baseline but weaning eight pigs per litter, the operation moves to a breakeven return to management and risk of $1.08 per hundredweight. With both nine pigs weaned and no increase in labor, the return is $3.54 per hundredweight. On the other hand, halving the sow culling rate to 12.5 percent may be too optimistic. At the same 25 percent culling rate as the baseline, and with eight pigs per litter and three times the baseline labor, a loss of $-4.63 results.

For the sow-pig nursery system, return to management and risk declines by $1.38 per hundredweight for the small operation and $1.13 for the large one, to $-3.39 and $0.80. An increase in pigs weaned per litter to 9 instead of 8.5 would bring the return to management and risk in the large operation to $1.98, slightly higher than the baseline. This system may have an advantage of reduced nursery mortality because the pigs are not moved at weaning. If 8.5 pigs were weaned but the four percent mortality were reduced to one percent, 0.25 more pigs would reach the grower stage and returns would be $1.55 per hundredweight.

A market price of $43 per hundredweight was assumed for the intact boar system, due to higher slaughtering and processing costs at a market weight of 210 pounds instead of the baseline 240 to reduce the chance of boar odor in the meat. With that lower price and fewer pounds of market animals over which to spread the cost of the breeding herd, this system does not appear competitive with the baseline system. At the small size, returns to management and risk, which were $-2.01 per hundredweight for the baseline system, decline to $-6.26. Returns to management and risk for the large system, which were $1.93 per hundredweight with the baseline system, fall to $-2.06. A sensitivity analysis indicated that returns would be less than the baseline $1.93 at any market weight below about 230.

10.5 Conclusions

This analysis suggests that there are good reasons for profit-maximizing swine producers to have moved toward confinement swine systems such as the large baseline system. This system provides a higher return than any of the alternatives considered. Returns are also positive for the large electronic sow feeder and turnaround gestation stall systems, with only a difference of $0.32 per hundredweight between the baseline and these alternatives. The sow-pig nursery system also has a positive return but one that is $1.13 per hundredweight less than the baseline. Small improvements in performance from those assumed here could make these systems more profitable than the baseline (Table 10.1).

Returns are negative for the large outdoor, intact boar and straw bedding systems. The impact of slaughtering costs and consumer acceptance on market boar prices are probably the least certain of any of the assumptions made in this study.

This is not a complete economies of size study, but did attempt to incorporate differences in building and manure storage construction costs between 120 and 505 sow sizes reflected in the Boeckh manual as well as productivity differences shown in the PigCHAMP record summaries. These resulted in a difference in return to management and risk of about four dollars per hundredweight for all of the systems except for the straw bedding one. In that system, which doubles the labor requirement and reduces the investment requirement, the difference between the sizes is $5.35.

The all-gilt, summer farrowing outdoor system shows a loss. Traditionally, Minnesota producers farrowing outside have also used cheaper finishing facilities than the state-of-the-art one assumed here or have purchased feeder pigs to fill the facilities when their own are not available. Whether these pigs would be available under a mandated move to outdoor farrowing seems questionable. Cheaper facilities may reduce feed efficiency and increase labor requirements, however, so that the results would probably still look unfavorable. Finishing facilities were not varied for this alternative because information was not available on the difference in feed and labor efficiency that would result. Purchasing feeder pigs is a realistic possibility for many producers. However, if outdoor production were mandated for all or most producers in the interest of animal welfare, seasonality would most likely increase and winter-farrowed feeder pigs would not be available. Slaughter, processing and distribution costs would also likely be affected.

It is not surprising that the relative profitability of the eight systems analyzed is very sensitive to the underlying assumptions. In general, however, the analysis indicates that two of the alternative systems, electronic sow feeders and turnaround stalls, have returns to management and risk that are very similar to the baseline systems. The remaining systems analyzed have lower returns. The type of analysis reported should be extended to a wider range of systems, and the detailed model presented should facilitate further work. While no effort is made here to judge the extent to which these systems enhance animal welfare, the analysis should aid meaningful economic evaluation of welfare-enhancing production systems that animal behavior research may suggest.

Table 10.1. Summary Comparison of Baseline and Alternative Systems

System	Pigs Weaned	Feed Efficiency	Investment	Labor Hours	Return to Management and Risk
	no./sow/ year	lbs./ lb.	$/ sow	hours/ sow/yr.	$/ cwt.
Large					
Baseline	21.7	3.58	$3,320	18.01	$1.93
Electronic Sow Feeder	21.7	3.58	3,313	18.57	1.84
Turnaround Stalls	21.7	3.61	3,333	18.21	1.61
Sow-Pig Nursery	19.1	3.64	2,971	17.13	0.80
Outdoor, Southern	18.7	3.66	2,381	18.87	-0.08
Intact Boar	21.7	3.25	3,060	17.28	-2.06
Outdoor, Northern	7.5	3.79	1,750	8.77	-3.33
Straw Bedding	19.3	3.69	2,747	37.99	-3.80
Small					
Baseline	20.6	3.60	$4,094	22.96	$-2.01
Electronic Sow Feeder	20.6	3.60	4,131	23.68	-2.29
Turnaround Stalls	20.6	3.63	4,120	23.15	-2.38
Sow-Pig Nursery	19.0	3.65	3,868	22.88	-3.39
Intact Boar	20.6	3.27	3,744	22.05	-6.26
Straw Bedding	18.3	3.72	3,234	48.45	-9.13

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