CONSTRUCTION RESOURCE USE OF TWO DIFFERENT TYPES AND SCALES OF IOWA SWINE PRODUCTION FACILITIES

P. J. Lammers, M. S. Honeyman, J. D. Harmon, J. B. Kliebenstein, M. J. Helmers

ABSTRACT. *As global populations and affluence rise, there is increasing demand for energy, animal protein, and construction materials. In many cases, available resource pools are insufficient to meet growing market demands, resulting in increased prices and competition for limited resources. This study evaluates key construction resources needed to build different types and scales of Iowa swine production facilities. Two types of facilities — conventional confinement and hoop barn-based — within farrow-to-finish pig production systems scaled to produce either 5,200 or 15,600 market pigs annually are examined. Conventional confinement facilities are typical of pork industry practice in the United States and are characterized by individual gestation stalls and 1,200 head grow-finish buildings with slatted concrete floors and liquid manure systems. The hoop barn-based alternative uses bedded group pens in hoop barns for gestation and finishing. Five building materials: concrete, steel, lumber, thermoplastics, insulation, as well as crushed rock and diesel fuel used for building site preparation are considered. Land surface area required for buildings and pig production infrastructure are also compared. Relative market costs of newly constructed swine facilities are compared under several material price scenarios. Using hoop barns for grow-finish and gestation results in lower construction costs. Increasing the scale of pig production results in lower construction costs per pig space, however the construction costs per pig space for a 5,200 head hoop barn-based complex is less than the construction costs per pig space for a 15,600 head conventional confinement system. In terms of construction resource use and cost, hoop barns for swine are a viable alternative that are less dependent on the scale of production than conventional confinement facilities.*

Keywords. *Building materials, Construction costs, Hoop barn, Swine production.*

Global population is projected to reach 9.2 billion people in 2050 and if realized will represent an increase of more than 360% over a 100-year time period (UN, 2007). Population in China and the United States is also projected to increase dramatically (UN, 2007). Those two countries lead the world in pork production and consumption, a trend that is likely to continue (den Hartog, 2005; FAO, 2006). Increased population and rising incomes have created increased market demand for energy, animal protein, and construction materials globally. Over time, increased market demand for available resources typically results in greater price competition for those resources. Thus it is appropriate to examine the relative efficacy of using construction resources to build different types and scales of animal protein production systems. This article examines the material use for constructing different types and scales of Iowa swine production facilities. Relative costs of building different types and scales of Iowa swine production facilities are also compared under different pricing scenarios. Information presented in this article constitutes an inventory of construction resources required for construction of pig production facilities. This inventory can be combined with additional information to conduct a life cycle analysis of pig production, however the present article is not a life complete cycle analysis of pig production facilities.

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METHODS

This project considers input of construction resources into different types and scales of swine production facilities based upon physical material flows. Two types of facilities—conventional confinement and hoop barn-based are considered within identically scaled farrow-to-finish production systems. The conventional confinement system is typical of pork industry practice in Iowa and is characterized by individual gestation stalls and 1,200 head grow-finish buildings with slatted concrete floors and liquid manure systems. The hoop barn-based alternative system uses group pens in bedded hoop barns for gestation and finishing. Both systems will use farrowing crates and climate controlled nursery facilities and are summarized in table 1. Resource use is related to volume of pig flow and so pig production systems sized to produce batches of either 400 or 1,200 pigs every 28 d, or 5,200 and 15,600 pigs annually are compared.

PIG FLOW REQUIREMENTS

PigCHAMP is a production record system widely used in the United States pork industry and summarized records of reproduction performance are available online (PigCHAMP,

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Table 1. Pork production systems compared.

Production Phase	System	
	Conventional	Hoop Barn-Based
Breeding and gestation	Individual stalls with deep pit	Group pens in bedded hoop barns
Farrowing[a]	Crates with pull plug system	Crates with pull plug system
Nursery	Pens with shallow pit	Pens with shallow pit
Grow-finish	Pens with deep pit	Pens in bedded hoop barns

[a] Manure from farrowing building stored in gestation pit (conventional) or adjacent outside storage pit (hoop barn-based).

Table 2. Pig flow parameters.[a]

Weaned pigs per litter (pigs)	9.2
Litters weaned per mated female (litters/yr)	2.3
Farrowing rate (litters born/sows mated)	77.6%
Nursery mortality rate	2.9%
Grow-finish mortality rate	3.9%
Sow herd replacement rate	60.0%
Pig age at weaning (d)	21.0
Maximum pig age at market (d)	180.0

[a] Based on USDA (2007) and PigCHAMP (2008).

2008). Average reproductive performance benchmarks for PigCHAMP users in 2004 and 2006 were used to calculate pig numbers and flow through breeding, gestation, and farrowing. The latest USDA survey of pig producers in the United States (USDA, 2007) reports days spent in a particular housing type as well as mortality rates during a specific growth phase. This information was used to calculate pig numbers and flow through nursery and grow-finish facilities. Pig flow parameters used to calculate space requirements are detailed in table 2. Table 3 details pig space needs for annual production at the level of 5,200 and 15,600 market pigs annually. The hoop-based system will require the same type and number of pig spaces as the conventional confinement system, although spaces will be distributed across more individual buildings.

Table 3. Pig spaces needed by production phase for two levels of annual pig production.

	5,200 Pigs		15,600 Pigs	
Production Phase	Spaces	Turns/yr	Spaces	Turns/yr
Breeding and gestation	310	na	900	na
Farrowing	48	13.0	140	13.0
Nursery	880	6.5	2,600	6.5
Grow-finish	1,600	3.3	4,800	3.3

Building Materials

The buildings examined are simplified design models that were generated to provide estimates of building material use. Building dimensions, layout, and material selection decisions for the examined facilities were determined by interviewing construction firms, facility managers, and industry consultants. Although the buildings are intended to be similar to actual facilities currently being built in Iowa they are not engineered designs. Application of the buildings or building components described should be limited to estimating material use of similar buildings. MidWest Plan Service publications (MWPS, 1987, 1989a, 1989b; Brumm

Table 4. Summary of pig facilities examined.

Production Level/Phase	Building Dimensions (m × m)	Area/Thermal Resistance (MJ/h°C)	Gross Area[a] (m^2/pig)	Net Area[b] (m^2/pig)	Description
5,200 pigs/yr					
Farrowing[c]	21.9 × 13.4	0.56	6.1	3.3	4 rooms of 12 crates, pull plug gutter to 2.4-m pit
Nursery	30.5 × 15.5	0.79	0.5	0.4	4 rooms of 22 pens, 1.2-m pit
Grow-Finish					
Conventional	92.0 × 15.5	6.38	0.9	0.8	4 rooms of 8 pens, 2.4-m pit
Hoop-based	21.9 × 9.1	1.0	1.0		8 hoop barns with 1 sort/load area, 1 pen/barn
Gestation					
Conventional	52.4 × 13.4	3.72	2.3	1.3	Individual gestation stalls, 2.4-m pit
Hoop-based	21.9 × 9.1	5.8	5.2		9 hoop barns, 2 groups pens with 36 feed stalls/barn
Storage	18.3 × 18.3				Bedding storage, 65% of area allocated to storage
15,600 pigs/yr					
Farrowing[c]	73.2 × 13.4	1.55	7.0	3.3	10 rooms of 14 crates, pull plug gutter to 2.4-m pit
Nursery	41.1 × 15.5	1.01	0.5	0.3	2 barns with 1.2-m pit, 4 rooms of 30 pens/barn
Grow-Finish					
Conventional	61.3 × 15.5	4.43	0.8	0.7	4 barns with 2.4-m pit, 1 room of 20 pens/barn
Hoop-based	21.9 × 9.1	1.0	1.0		24 hoop barns with 4 sort/load areas, 1 pen/barn
Gestation					
Conventional	70.7 × 13.4	4.78	2.1	1.3	2 barns with 2.4-m pit, individual gestation stalls
Hoop-based	21.9 × 9.1	5.5	5.0		25 hoop barns, 2 groups pens with 36 feed stalls/barn
Storage	18.3 × 18.3				Bedding storage, 2 entire hoop barns

[a] Total area under cover.
[b] Total area under cover minus walkways and alleys.
[c] Manure storage for the farrowing facility in the conventional confinement system is the 2.4-m deep pit under the gestation facility. Manure storage for the farrowing facility in the hoop barn-based system is a separate 2.4-m deep pit adjacent to the farrowing facility.

et al., 2004; Harmon et al., 2004; Koenig and Runestad, 2005) were used as a basis for all designs. Table 4 provides a basic summary of building dimensions and layout. The farrowing facility used by conventional confinement system and the hoop barn-based system is identical in terms of size and room set-up. Both systems also use a pull-plug manure system. However, in the conventional confinement system the pull-plug manure system is connected through underground pipe to the gestation barn's 2.4-m deep manure storage tank. This is typical of conventional confinement facilities in the United States. In the hoop barn-based system, the gestation facilities are hoop barns and do not have pits for liquid manure storage. Thus in the hoop barn-based system, farrowing facilities must include a 2.4-m deep pit appropriately sized for liquid manure storage from the farrowing facility. For this comparison the hoop barn-based system's farrowing facility includes an exterior pit. The hoop barn-based farrowing pit in this analysis is a 3.6-m wide, 2.4-m deep pit that runs the length of the building (21.9 m long for the 5,200 market pig system and 73.2 m long for the 15,600 market pig system).

Farrowing and nursery facilities consist of a 2.4-m high framed wall around the entire building. The exterior wall is sheeted with steel and the wall that is in contact with the pigs is covered with commercially available high-density polyethylene sheeting. Appropriately designed wood rafters sit on top of the walls. Steel sheeting is assumed for the roof and ceiling of farrowing and nursery facilities.

The building shell for breeding and gestation and grow-finish within a facility type are similar. The conventional system begins with a 2.4-m deep pit and concrete slats. On top of the pit wall a 1.4-m high concrete sidewall is poured around the entire building. A 0.9-m high framed wall is set on top of the concrete walls. The buildings described are rectangles, the short sides of the rectangles are enclosed with exterior steel and interior high-density polyethelene sheeting. The long walls of the buildings are covered by a 0.9-m tall curtain that runs the length of the building. Above the curtain a 0.3 m header is assumed with appropriately designed lumber rafters sitting on top of the building wall. Steel sheeting is assumed to cover the roof and ceiling in conventional grow-finish and gestation facilities.

Hoop structures for swine are less complex in their construction. A hoop barn is a Quonset™-shaped structure that has been previously described (Honeyman et al., 2001; Brumm et al., 2004; Harmon et al., 2004). Hoop barn sidewalls are assumed to be 1.5-m high and consist of wooden posts and sidewalls. Tubular steel arches are attached to the posts, forming a hooped roof. A UV-resistant, high-density polyethylene tarp is pulled over the arches and fastened to the sidewalls. It is assumed that the entire floor area is covered with reinforced concrete. Hoop barns for grow finish have a 0.8-m high elevated pad covering one-third of the floor area. Feeders and waterers are located on this pad. In hoop barns for gestation a 3.0-m wide, 0.8-m high pad is set along one of the long side-walls with feed stalls located on top of the concrete pad. An appropriate waterer is located on the other side of the building on top of a small (1.8 × 0.9 m), 0.8-m high concrete platform.

Five primary building materials are reported: concrete, steel, lumber, insulation, and thermoplastics. Each material is not a homogenous entity, but for this comparison material specifications have been standardized and material use is reported by mass. For this comparison, the volume of each material was calculated from a list of materials for every building and then multiplied by a density factor appropriate for each material. Table 5 presents material density assumptions used to calculate mass of materials required for a particular building. Current prices of building materials were collected by personal interview with various suppliers operating in Iowa, the leading pig producing state in the United States. The estimated market values of construction materials are summarized in table 5.

Land Surface Area

Multi-site pig production is common in the United States, however for this comparison it is assumed that one building site is used for all phases of production. Individual buildings detailed in table 4 were arranged on a scaled model site according to the following guidelines. First, a distance of at least 46 m was maintained between distinct phases of production — farrowing, nursery, grow-finish, and gestation. Secondly, a minimum of 6-m distance was maintained between individual buildings within a production phase — between grow-finish barns for example. Finally, a 6-m buffer was added to the edge of all buildings lining the perimeter of the building site. For the hoop barn-based building sites, storage hoops for bedding were positioned near the gestation and grow-finish hoop barns. Hoop barns used for storage were allowed a 6-m separation between other buildings, but were not required to be separated by 46 m from buildings housing pigs. Access roads to facilities were then outlined on the scaled model. A perimeter was drawn around the entire building site to delineate total land surface area needed for buildings, access roads, and buffers. The market value of land suitable for building swine facility complexes was assumed to be $3,200/ha for initial analysis.

Building Site Preparation

It was assumed that the building site was previously furnished with sufficiently sized wells, electrical mains, and a main entrance driveway. Building site preparation includes

Table 5. Density and estimated value of construction materials examined.

Material	Density (g/cm^3)	Est.Value ($/kg)	Examples and Uses
Concrete[a]	2.40	$0.04	Building foundations, walls, manure storage, slats
Steel[b]	8.08	$1.14	Concrete reinforcing bar, siding, gating, hoop trusses
Lumber[c]	0.53	$0.23	Building frame, trusses
Thermoplastics[d][e]	0.95	$1.00	Flooring, pens, building curtains, hoop barn tarps
Insulation[f][g]	0.03	$0.59	Ceiling and walls of non-hoop buildings
Crushed rock[h]	2.75	$0.02	Access roads

[a] Koenig and Runestad (2005).
[b] BSCI (2008).
[c] Rao (2008).
[d] High density polyethylene.
[e] BT (2008).
[f] Loose fill cellulose.
[g] USDOE (2005).
[h] Hammond and Jones (2008).

excavating manure storage pits, backfilling completed manure storage pits, grading the entire building site, and building access roads. Earthwork for nursery, conventional gestation, and conventional grow-finish buildings was calculated by multiplying the building dimensions by the depth of the manure storage pit. The building dimensions and manure storage pit depths given in table 4 were increased by 0.5 m and then used to calculate volume of soil to be excavated. The volume of backfill required for each building was calculated by subtracting the volume of the manure storage pit from the volume excavated. Grading of the building site was calculated by multiplying the site's entire surface area by 0.3 m and is used to estimate the earthwork needed to reposition soil that was excavated in excess of the backfill for manure pits, as well as prepare the building site for farrowing facilities and hoop barn construction. In the conventional confinement system, manure from the farrowing facility is stored in the gestation barn pit and no additional earthwork was included in the estimate. The farrowing facility used in the hoop barn-based systems has a manure storage pit and so excavation and backfilling was calculated for a 2.4-m deep manure storage pit adjacent to the farrowing facility. Access roads were calculated by multiplying the length of each road by a width of 3 m and a depth of 0.9 m. Each access road was finished by covering with a 0.3-m thick layer of crushed rock.

Appropriately sized machines were selected for earthwork based on discussions with equipment company representatives. The time required to complete each task was calculated using machine capacities and construction estimating references (RES, 1990; Mossman and Plotner, 2006). Hours of operation were then multiplied by fuel use per hour values presented by Caterpillar Inc. (2008). Initial costs analyses assume diesel fuel is valued at $1.00/L.

Labor and Material Costs

Labor and material costs were first calculated for each building based on the material list for each building and data presented by Mossman and Plotner (2006). Prices reported by Mossman and Plotner (2006) represent the estimated national average for industrial and commercial construction projects. National averages can be indexed for different locations providing a more precise cost estimate. Because costs in Iowa for most labor and material divisions relevant to construction of swine facilities were below the national average (Mossman and Plotner, 2006), national averages are reported. Labor and material costs are highly dependent on specific activities, for example the labor cost of excavating a cubic meter of soil is nearly twice the labor costs of grading the same volume of soil (Mossman and Plotner, 2006). The reported comparisons used task specific labor and material costs to calculate total project costs.

Construction Cost Sensitivity to Price Change

The sensitivity of the total construction cost for a given type and scale of swine facilities to changes in prices of concrete, steel, land, labor, and energy were examined. Sensitivity analysis for concrete, steel, land, and labor was performed by multiplying the reported cost associated with each resource by price increases of different magnitudes and then adding the additional cost to the original construction costs. Sensitivity analysis for energy costs increases required calculating the impact of energy prices on all resources. Embodied energy is the energy used to generate a particular material. Hammond and Jones (2008) detail the embodied energy of building materials from cradle-to-gate. In other words the embodied energy values used in our analysis account for energy required to gather and process raw and recycled materials into construction resources but does not consider the energy associated with a construction material after it has been produced. There is no universally accepted value of the embodied energy of a specific material, but using a readily available reference that includes all examined materials (Hammond and Jones, 2008) ensures that materials are compared on an even basis. Two building resources considered, diesel fuel and thermoplastics, are almost entirely composed of petroleum and thus are very dependent on the price of energy. The relative magnitude of embodied energy of concrete, steel, lumber, and insulation relative to thermoplastics is 0.01, 0.32, 0.10, and 0.03. For example, if a given mass of thermoplastic has an embodied energy value of 100 MJ, the embodied energy values of equivalent masses of concrete, steel, lumber, and insulation would be 1, 31, 10, and 3 MJ, respectively. If all energy prices increase by 25%, the price of thermoplastics and diesel fuel are assumed to also increase by 25%. The market price of concrete, steel, lumber, and insulation are assumed to increase proportionally to their embodied energy value relative to thermoplastics.

Results

Table 6 presents construction resource use for swine production facilities. Increasing the number of pigs sold annually resulted in increased use of construction resources. However in most cases tripling pig production space increased construction resource use by less than 300%. There was little overall difference in the magnitude of resource use between the two scales of pig production within a facility type. More land area is necessary to site the hoop barn-based systems, but fuel use to perform earthwork operations is half of what conventional confinement facilities require. Generally fewer building resources were required for the hoop barn-based systems.

Estimated construction costs for swine production facilities based on Mossman and Plotner (2006) are summarized in table 7. The farrowing facility for the hoop barn-based system includes a 2.4-m manure storage pit, while in the conventional confinement system manure from the farrowing facility is stored in the gestation pit. This difference results in the farrowing facility for the hoop-based systems costing 11% to 14% more than the farrowing facility for the conventional confinement systems. The major difference between the hoop barn-based system and the conventional confinement system is the cost of building grow-finish facilities. Estimated construction costs of hoop barns for grow-finish pigs are 27% to 41% of the construction costs of similarly sized conventional facilities. Estimated gestation facility costs are below previous estimates (Lammers et al., 2008), however the current estimate does not include ventilation or water systems. Building hoop barn-based gestation is estimated to cost 31% to 64% less than conventional confinement facilities with the major differences from less concrete and steel being used in the hoop barns. Both systems include individual gestation stalls and

Table 6. Construction resource use for swine production facilities.

Facility Type	Pigs Sold Annually	Conventional 5,200	Conventional 15,600	Hoop Barn-Based 5,200	Hoop Barn-Based 15,600
Farrowing[a]	Concrete (kg)	150,464	451,393	287,534	691,769
	Steel (kg)	20,508	32,092	22,499	38,404
	Lumber (kg)	6,651	19,561	6,651	19,561
	Thermoplastics (kg)	16,053	30,172	12,466	26,585
	Insulation (kg)	2,433	6,415	2,433	6,415
	Diesel fuel (L)	0	0	38	124
Nursery	Concrete (kg)	288,653	782,598	288,653	782,598
	Steel (kg)	27,093	64,662	27,093	64,662
	Lumber (kg)	12,468	26,238	12,468	26,238
	Thermoplastics (kg)	12,159	30,892	12,159	30,892
	Insulation (kg)	3,192	5,110	3,192	5,110
	Diesel fuel (L)	46	466	46	466
Grow-Finish	Concrete (kg)	1,237,294	3,435,800	678,191	2,074,200
	Steel (kg)	28,740	113,264	11,024	33,336
	Lumber (kg)	33,569	89,960	18,560	56,136
	Thermoplastics (kg)	3,084	4,792	1,074	3,216
	Insulation (kg)	6,759	17,576	0	0
	Diesel fuel (L)	802	2,146	0	0
Gestation	Concrete (kg)	696,669	1,709,790	606,078	1,683,550
	Steel (kg)	38,329	107,144	27,333	75,925
	Lumber (kg)	13,115	34,920	16,812	46,700
	Thermoplastics (kg)	711	1,610	1,350	3,750
	Insulation (kg)	3,402	9,116	0	0
	Diesel fuel (L)	281	468	0	0
Bedding storage	Concrete (kg)	0	0	56,296	173,218
	Steel (kg)	0	0	2,137	9,574
	Lumber (kg)	0	0	268	826
	Thermoplastics (kg)	0	0	124	380
Access Roads	Crushed rock (kg)	132,000	264,000	303,600	475,200
	Diesel fuel (L)	34	64	78	121
Site Preparation	Diesel fuel (L)	399	830	591	1,110
Total for all production facilities	Concrete (kg)	2,373,080	6,379,581	1,916,752	5,405,335
	Steel (kg)	114,670	317,162	90,086	221,901
	Lumber (kg)	56,029	151,074	44,985	129,856
	Thermoplastics (kg)	32,007	67,466	37,123	64,823
	Insulation (kg)	19,361	51,017	9,210	24,325
	Crushed rock (kg)	132,000	264,000	303,600	475,200
	Diesel fuel (L)	1,562	3,910	753	1,700
	Land (m^2)	11,868	24,870	16,671	32,117
	Labor (h)	23,000	45,900	14,300	39,300

[a] Manure storage for the farrowing facility in the conventional confinement system is the 2.4-m deep pit under the gestation facility. Manure storage for the farrowing facility in the hoop barn-based system is a separate 2.4-m deep pit adjacent to the farrowing facility.

gestation stalls are a significant contributor to the total mass of steel in both types of facilities. Although stalls used for feeding are not as heavy as stalls used for gestation, this analysis assumes gestation stalls are used for housing gestating sows in the conventional confinement system and for feeding gestating sows in the hoop barn-based system. The hoop barn-based system requires storage facilities for bedding as well as more land, crushed rock, labor, and equipment use for site preparation. Still this greater use of resources did not negate the cost advantages presented by using hoop barns for grow-finish and gestation.

The estimated construction cost per market pig space is very different for the two systems. Estimated construction costs per pig space are lowest for the 15,600 head hoop barn-based complex and both hoop barn-based systems cost less per pig space than any conventional confinement system considered. Increasing the size of the operation resulted in lower construction costs per pig space. Moving from 5,200 to 15,600 head in the conventional confinement system results in a construction cost reduction of 38% per pig space. In the hoop barn-based system the same change in size only reduces construction costs by 13% per pig space. Labor costs

Table 7. Estimated construction costs for swine production facilities.[a]

		Conventional		Hoop Barn-Based	
Facility Type	Pigs Sold Annually	5,200	15,600	5,200	15,600
Farrowing[b]	Materials	$87,008	$180,488	$92,593	$211,211
	Labor	$36,789	$92,372	$50,042	$133,950
	Total/farrowing crate	$2579	$1,949	$2,972	$2,465
Nursery	Materials	$86,678	$233,986	$86,678	$233,986
	Labor	$42,913	$107,006	$42,913	$107,006
	Total/pig space	$147	$131	$147	$131
Grow-Finish	Materials	$310,033	$764,378	$99,996	$307,094
	Labor	$192,205	$250,348	$36,690	$111,928
	Total/pig space	$314	$211	$85	$87
Gestation	Materials	$264,429	$418,357	$104,823	$291,179
	Labor	$230,703	$251,018	$49,131	$136,475
	Total/sow space	$1,597	$744	$497	$475
Storage	Materials	0	0	$12,725	$25,832
	Labor	0	0	$4,898	$9,796
	Total/m^2	0	0	$53	$53
Site preparation	Land	$23,200	$48,800	$32,800	$63,200
	Materials	$10,980	$21,053	$25,283	$39,537
	Labor	$723	$1,505	$1,071	$2,013
	Equipment	$2,222	$4,623	$3,289	$6,181
	Total/m^2	$3.13	$3.06	$3.75	$3.45
Subtotal material and land		$782,328	$1,667,062	$454,898	$1,172,039
Subtotal labor and equipment		$505,555	$706,872	$188,034	$507,349
Total		$1,287,883	$2,373,934	$642,932	$1,679,388
Construction cost per market pig sold		$248	$152	$124	$108

[a] Mossman and Plotner (2006).

[b] Manure storage for the farrowing facility in the conventional confinement system is the 2.4-m deep pit under the gestation facility. Manure storage for the farrowing facility in the hoop barn-based system is a separate 2.4-m deep pit adjacent to the farrowing facility.

are highly dependent upon type of activity. Building conventional confinement facilities and hoop barn-based facilities require different amounts of different types of labor. This is illustrated by the reported differences in reduction of building cost per pig space between conventional confinement and hoop barn-based systems.

Labor and material costs were also estimated for each swine facility complex using mass and market values of materials reported in tables 5 and 6. Hours of labor were estimated based on Mossman and Plotner (2006). An initial value of $20/hr was assumed for all construction labor. Table 8 presents estimated construction costs for swine facility complexes based on material use calculations. Overall costs estimated based on material mass is less than costs estimated according to Mossman and Plotner (2006). Costs presented by Mossman and Plotner (2006) are national averages, however, costs used in the material mass method are more accurate for Iowa. The cost of building swine facilities on a market pig space basis follows a similar pattern regardless of the method of estimation. Based on material mass the cost per pig space for a hoop barn-based facility sized to produce 15,600 pigs is $92, and the hoop barn-based facility producing 5,200 pigs annually can be built for a cost of $107/pig space. Both are lower than the cost of building a 15,600 head conventional confinement facility which in turn is less than the construction cost of a 5,200 head conventional confinement facility. In the conventional confinement system, increasing size from 5,200 to 15,600 head results in reducing construction costs by 25%. In the hoop barn-based system increasing the size of facilities from 5,200 to 15,600 head results in a 14% reduction in construction costs.

Actual building costs are likely to be different than the estimates presented in tables 7 and 8. However, it is expected that the distribution of costs within a facility type and the magnitude of differences between conventional confinement facilities and hoop barn-based systems remain relatively constant. For example, approximately 70% of the costs of building swine facilities are material costs with the remainder being allocated to labor costs. Systems that use bedded hoop barns for gestation and grow-finish cost less to construct than conventional confinement facilities for identically scaled operations. Increasing the total volume of pigs produced results in reduced construction cost per pig space, however the hoop barn-based system producing 5,200 pigs annually costs less to construct per pig space than the conventional confinement facilities producing 15,600 pigs annually regardless of the method used to estimate construction costs.

Results from table 8 were used to compare the effect of construction resource price changes on the total costs of different types and scales of pig facilities. Construction cost

Table 8. Estimated construction costs for swine facility complexes based on material mass.[a]

	Conventional		Hoop Barn-Based	
Pigs Sold Annually	5,200	15,600	5,200	15,600
Concrete	$94,932	$255,183	$76,670	$216,213
Steel	$130,724	$361,565	$102,698	$252,967
Lumber	$12,887	$34,747	$10,346	$29,867
Thermoplastics	$32,007	$67,466	$37,123	$64,823
Insulation	$11,423	$30,100	$5,434	$14,352
Crushed Rock	$2,640	$5,280	$6,072	$9,504
Fuel	$1,562	$3,910	$753	$1,700
Land	$23,200	$48,800	$32,800	$63,200
Labor[b]	$460,000	$918,000	$286,000	$786,000
Total	$769,375	$1,725,051	$557,896	$1,438,626
Construction cost per market pig sold	$148	$111	$107	$92

[a] Calculated by multipling material masses reported in table 6 by estimated market values of materials presented in table 5.
[b] Calculated by multiplying hours of labor reported in table 6 by $20/h.

sensitivity to changes in the value of concrete and steel are presented as figures 1 and 2. More concrete and steel per pig space are used in the conventional confinement facilities. Increasing the cost of concrete and steel increases the construction costs for all type and scales of pig facilities. If resource prices change uniformly for all types and scales of pig production facilities, the construction costs per market pig sold for a conventional confinement facility sized to produce 15,600 market pigs annually is very similar to the construction costs per market pig sold for a hoop barn-based system producing 5,200 market pigs annually. If concrete or steel prices increase by 25%, construction costs per market pig sold increase by 3% to 4% or 4% to 5%, respectively. Doubling the price of concrete increases construction costs per market pig sold by 15% to 18%. A doubling in the price of steel results in a 21% to 25% construction cost per market pig sold increase. Even if resource prices do not change uniformly for all types and scales of pig production facilities it is only at the extremes that the generalized cost advantage of building hoop barn-based systems sized to produce 15,600 market pigs annually do not hold. For example, if a firm building the hoop barn-based system sized to produce 15,600 market pigs annually pays double the price for steel that a construction firm building the conventional confinement facilities sized to produce 15,600 market pigs annually can obtain, then construction costs for the conventional confinement facility are approximately 1% less than the construction costs for the hoop barn-based system.

Pig production in hoop barns allows more space per pig, and requires more land surface area. Figure 3 details construction cost sensitivity to changes in land values. Because the cost of land is a relatively small factor in the total construction cost of a pig facility, construction costs are not very responsive to land value increases. A doubling of land values only increases the total construction costs per market pig sold by 3% to 8% regardless of type and scale of facility. The construction costs of hoop barn-based systems are more sensitive to land value changes than conventional confinement. However land values would have to increase more than 2,000% (data not shown) before conventional confinement

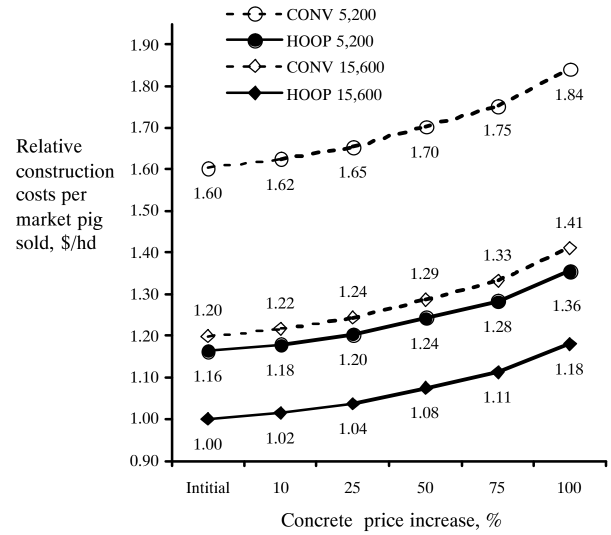

Figure 1. Construction cost sensitivity to change in concrete prices for different types and scales of pig production facilities. HOOP or CONV and 15,600 or 5,200 represent hoop barn-based pig production or conventional confinement facilities scaled to produce 15,600 or 5,200 market pigs annually.

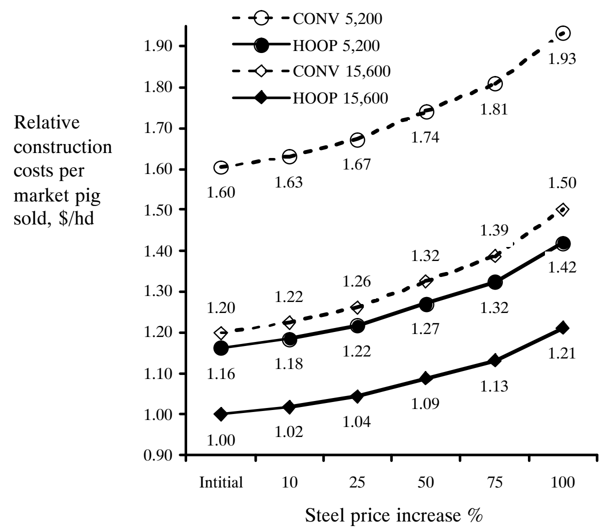

Figure 2. Construction cost sensitivity to change in steel prices for different types and scales of pig production facilities. HOOP or CONV and 15,600 or 5,200 represent hoop barn-based pig production or conventional confinement facilities scaled to produce 15,600 or 5,200 market pigs annually.

facilities have a construction cost advantage over hoop barn-based systems due to land costs.

Labor is the single largest construction expense in building pig facilities. Figure 4 details the effect changing labor values have on the total construction costs of different types and scales of pig production facilities. Increasing the size of the production facilities delivers construction cost per market pig sold advantages. In the conventional confinement system construction costs per market pig sold for the facilities sized to produce 5,200 market pigs annually are 33% to 41%

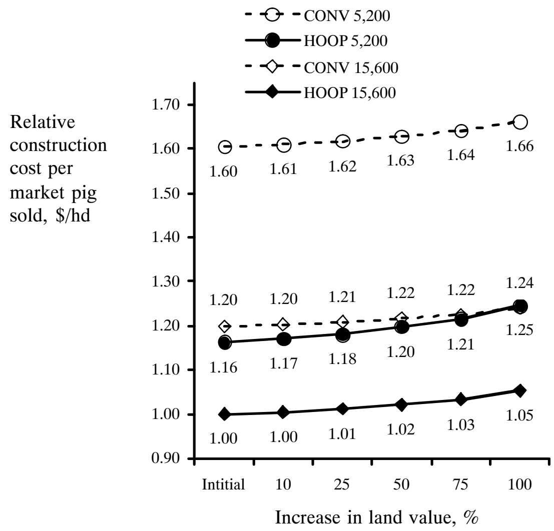

Figure 3. Construction cost sensitivity to change in land values for different types and scales of pig production facilities. HOOP or CONV and 15,600 or 5,200 represent hoop barn-based pig production or conventional confinement facilities scaled to produce 15,600 or 5,200 market pigs annually.

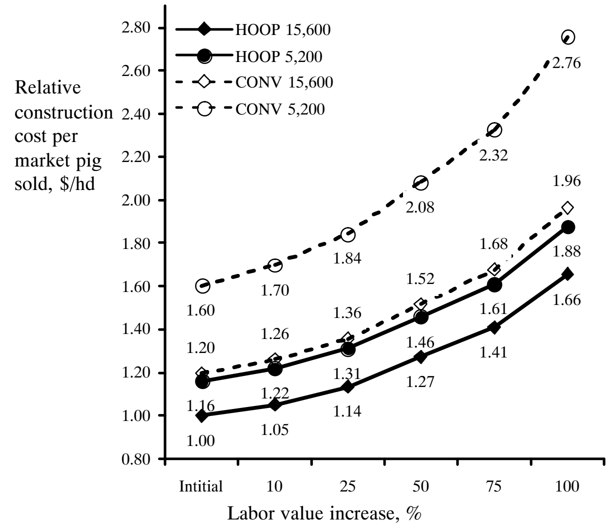

Figure 4. Construction cost sensitivity to change in construction labor prices for different types and scales of pig production facilities. HOOP or CONV and 15,600 or 5,200 represent hoop barn-based pig production or conventional confinement facilities scaled to produce 15,600 or 5,200 market pigs annually.

higher than construction costs per market pig sold for the facilities sized to produce 15,600 market pig under the different labor value scenarios. The hoop barn-based system construction costs per market pig sold for facilities sized to produce 5,200 market pigs annually are only 13% to 16% higher than the construction costs per market pig sold for the facilities sized to produce 15,600 market pig annually. The firm building hoop barn-based systems at the 15,600 market pigs per year scale would have to pay approximately 40% more for labor than the firm building conventional confinement facilities at the 15,600 market pigs per year scale before construction costs are higher for the hoop barn-based system.

The effect of changing energy prices on the total construction costs of different types and scales of pig production facilities are presented as figure 5. Systemic increases in the price of energy has more dramatic impact on the relative construction cost per market pig at the 10% level than other resource price increases. Increasing energy prices by 10% results in a 7% to 8% increase in construction costs for all facility types and scales. Increasing energy prices by 25% results in a 8% to 10% increase in total construction costs from initial conditions. Energy price increases ranging between 10% and 75% result in total construction costs increasing linearly at rate of 6% to 8%. Doubling the value of energy resources causes a spike in total construction costs. Doubling the value of energy resources increases the construction costs of the examined pig production facilities by 26% to 31%.

Based on construction costs per market pig sold, there is more incentive to increase the scale of pig production in conventional confinement systems than in hoop barn-based systems. For all construction resource price scenarios examined the difference between the 5,200 and 15,600 market pig firms was greater for the conventional facilities than the hoop barn-based systems. If all firms have access to construction resources at the same price, construction cost per market pig sold for a hoop barn-based production facility

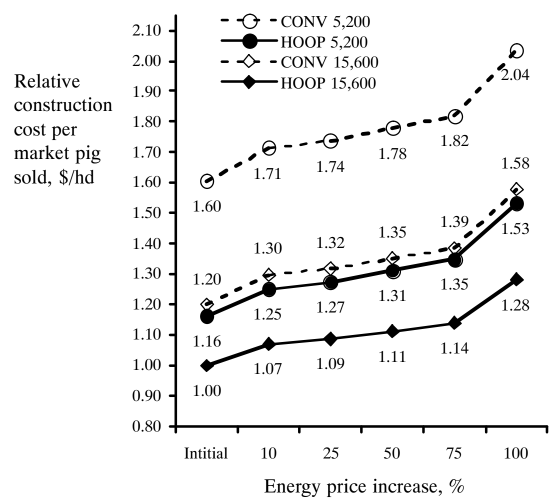

Figure 5. Construction cost sensitivity to change in energy prices for different types and scales of pig production facilities. HOOP or CONV and 15,600 or 5,200 represent hoop barn-based pig production or conventional confinement facilities scaled to produce 15,600 or 5,200 market pigs annually.

sized to produce 5,200 market pigs annually is less than the construction costs per market pig sold for a conventional confinement facility producing 15,600 market pigs annually. Firms that are building facilities on a larger scale may be able to achieve some resource pricing advantages over smaller firms. However, it is unlikely that a conventional confinement swine facility sized to produce 15,600 pigs annually would have more negotiating clout than a hoop barn-based swine facility producing the same number of pigs.

CONCLUSIONS

This article examines construction resources for different types and scales of Iowa swine production facilities. The environmental impact of pig production also depends on production efficiency of different systems, energy use by those systems, resulting emissions, and nutrient cycling within a production system. The present comparison of construction resource use does not provide a complete life cycle analysis of pork production. Rather it provides a construction resource inventory that can later be combined with future analyses of operating different swine production facilities to generate a more systemic life cycle analysis of pork production.

Hoop barn-based swine facilities use less concrete, steel, lumber, insulation, diesel fuel, and labor to construct than identically scaled conventional confinement facilities. More crushed rock and land is needed for hoop barn-based swine facilities but these are relatively small contributors to the total construction costs of swine facilities. The relative impacts of resource price changes are similar for both types and scales of swine facilities examined. The construction costs of hoop barn-based swine facilities are more sensitive to land prices than conventional confinement facilities, but land price is a relatively minor factor in total construction costs. Increasing the scale of facilities from 5,200 to 15,600 pigs reduces construction costs per pig space regardless of system, but the magnitude of reduction is less for hoop barn-based facilities than conventional confinement facilities. Regardless of method for estimating construction cost, a swine production facility producing 5,200 market pigs annually and using hoop barns for gestation and grow-finish costs less to build per pig space than a conventional confinement swine facility producing either 5,200 or 15,600 market pigs annually. In terms of construction resource use and costs, hoop barns for swine are a lower cost alternative that is less scale dependent than conventional confinement facilities. As competition for construction resources increase the cost advantages of building hoop barn-based swine facilities is expected to increase.

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