Prediction of Dairy Housing Construction Costs

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ABSTRACT

Dairy farms in Galicia and elsewhere in Europe are going through a transition phase to adapt to modern dairy technology, improve labor efficiency, and increase in size and scale. Expanding a dairy herd and building housing for more cows can be very expensive. A poor decision during expansion can result in serious financial difficulties even to the point of making the farm economically unviable. Dairy managers must carefully evaluate existing alternatives and must select an optimal strategy. To aid this decision, a computer spreadsheet application has been developed that predicts the cost per cow and cost per unit of area of alternative designs as functions of the number of cows to be housed. The spreadsheet is, in principle, applicable to a wide variety of designs and to housing for livestock other than dairy cattle. However, the current database allows comparison among six of the dairy housing designs that have been used most widely in Galicia in recent years. From projected financial results of the developed model, it was concluded that differing designs were preferred for different farm circumstances. Preferred designs for farms with 60 to 200 cows were either four rows of facing free stalls or four rows of tail-to-tail free stalls, which have virtually the same costs. Whereas for farms with fewer than 60 cows, the preferred design was two rows of tail-to-tail free stalls, designs with three rows of free stalls were generally more costly per cow. Results of design calculations must be integrated with other farm management considerations in choosing a particular design. (**Key words:** dairy farm, investment, cost, design)

INTRODUCTION

Galicia, a Spanish autonomous community with over 3 million inhabitants, constitutes the northwestern corner of Spain (Figure 1).

Figure 1. Geographical location of Galicia.

Galicia still includes some 40% of Spanish dairy farms even though drastic structural changes have reduced dairy farm numbers from nearly 137,000 to about 37,500 over the past 20 yr, while simultaneously increasing the number of cows per farm (Table 1).

Concentration of the dairy industry is still under way. For owners of surviving, expanding farms there is considerable economic outlay, particularly for construction of larger, more modern dairy housing. These changes, which are the result of adaptation of modern

Table 1. Distribution of Galician dairy farms by size in 1980 and 1999.¹

1980		1999	
Cows/farm	No. of farms	Cows/farm	No. of farms
1–4	91,980	1 to 19	22,767
5–9	36,970	20 to 49	11,088
≥ 10	7,830	50 to 99	3,164
		100 to 199	445
		200 to 299	42
		300 to 499	15
		> 500	4
Total	136,780	Total	37,525

¹Source: Instituto galego de estatística, 2000.

Table 2. Descriptions of the layouts of the six designs.

Design	Description
T1	Layout with two rows of facing free stalls
T2	Double design of T1 with four rows of facing free stalls
T3	Layout with two rows of tail to tail free stalls
T4	Double design of T3 with four rows of tail to tail free stalls
T5	Layout with three rows of free stalls
T6	Layout with three rows of free stalls

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Figure 2. Transverse sections through the six free-stall barn designs considered in this study.

Table 3. Characteristics common to the free stall barn designs considered.

Characteristic	Type chosen	
Site level	600 to 800 m above sea level, normal wind exposure (NTE-ECV zone X)	
Ventilation	Natural ventilation	
Structure	Prefabricated reinforced concrete beams rooted in square pier footings	
Roofing	95% corrugated fiber cement sheets, 5% translucent corrugated sheets, slope 10%, ridge cap ventilation	
Walling	Breeze blocks	
Flooring	Concrete over stone chips	
Stalls	Freestalls, hot-dip galvanized steel tubing dividers	
Cleaning equipment	Automatic scraper	
Fittings	Galvanized iron sheeting	
Measurements	Symbol	Value (m)
Number of stalls rows	N_F	According to design (Figure 2)
Number of cows	N	$N = \text{Number of stalls}$
Stall length	L_{CU}	2.5
Stall width	A_{CU}	1.25
Feed-space width	L_{CO}	0.75
Transverse alley width	A_{PC}	≥ 2.5 (but constant)
Number of transverse alleys	N_{PC}	At least one per 20 stalls per row
Feed alley width	A_{PRA}	4.0 to 4.5
Free-stall alley width	A_{PRP}	3.0
Width of feed table(s) plus driveway	A_{PA}	4.2 (table + driveway) 5.2 (table + driveway + table)
Total interior width	A_{INT}	$A_{INT} = L_{CU} N_F + A_{PRA} + A_{PRP} + A_{PA}$
Total interior length	L_{INT}	$L_{INT} = N A_{CU} / N_F + N_{PC} A_{PC}$
Column width	E_P	0.3 to 0.4
Between column distances	Sep	$Sep = (L_{INT} + E_P) / N_V$
Column-to-column bays	N_V	Function of Sep (6 to 7) and L_{INT}

Figure 3. Relationships among geometrical parameters.

dairy technology, are intended to allow dairy managers to operate with lower investment per cow and to improve the quality of life of the dairy farm owners and workers. To be successful, the manager should attempt to develop business plans and facilities that are flexible. All facilities should be designed to allow for future expansion, plus offer safe and comfortable conditions for both the animals and workers (Palmer, 1999).

The choice of the design and size of dairy housing influences at least three factors affecting production and costs: the environmental conditions and productivity of the cattle, the efficiency of operations, and financial costs (Karzes, 2000). The influence of various environmental factors on the health and productivity of cattle has been confirmed by numerous authors (e.g., Hill et al., 1973; Harmon et al., 1992; Longenbach et al., 1999; Miller et al., 2000). The efficiency of operations is continually increasing thanks to improvements in equipment, in the working conditions of farm workers [for the importance of adequate lighting, see Beck (1995)] and in management systems [see, for example, Longenbach et al. (1999) on feed bunk requirements, and Meyer et al. (1999) on manure management]. The importance of comparing investment options as regards their associated financial costs has been stressed by many (see, for example, Ministère de l'agriculture, 1982; Hives, 1985; Hartmann, 1995; Kobayashi et al., 2000; and Mariño, 2001).

One of the decisions most critical for final construction costs is the initial choice of basic design (Trueba and Marco, 1986). To aid this decision, we have developed a computer spreadsheet application that predicts the cost per cow and cost per unit area of particular designs as functions of the number of cows to be housed. Although in principle applicable to a wide variety of designs, and to housing for livestock other than dairy cattle, its current database allows comparison among six of the dairy housing designs that have been used most widely in Galicia in recent years.

MATERIALS AND METHODS

On the basis of examination of all the dairy housing facilities constructed in Galicia in the period 1997 to 2000, and given the impossibility of taking all possible construction variables into account, we chose to analyze the six free-stall barn designs shown in Figure 2 and Table 2 assuming common specifications for siting, materials, basic equipment, and unit measurements; Table 3 and Figure 3 list some of the more important of these factors.

The siting and structural characteristics and measurements indicated in Table 3 were used, assuming between-column distances *Sep* of 6 to 7 m, to calculate the parameters and stresses of beams, purlins, and columns in accordance with Spanish official building regulations (Ministerio de Fomento, 1999: EHE Art. 42, 43, 59; Ministerio de Fomento, 1993). In the event, in the *Sep* range considered *Sep* proved not to influence column width *Ep*, and *Sep* was accordingly calculated as the largest distance in the range 6 to 7 m that was compatible with the geometrical relationship.

T-2 FREESTALL BARN DESIGN BUDGET

h. 80		Sup. 6.08			
Code	Uds.	Description	Measure- ment	Price (Euros)	Amount (Euros)
01# SOIL MOVEMENTS					
MOV1.01	m3	Retreat and heaped of vegetable soil	314.88	1.36	428.24
MOV1.02	m3	Mechanical excavation in compact soil	52.10	6.76	352.20
MOV1.03	m3	Load and transport of soil	386.98	2.60	954.15
Total chapter 01#					1,734.59
02# FOUNDATIONS					
CIM2.01	m3	Cleaning concrete	8.44	48.08	405.80
CIM2.02	m3	HA-25/P/20/IIa m foundations and beams	43.66	111.19	4,854.56
Total chapter 02#					5,260.36
03# DRAINS					
SAN3.01	m	PVC gutter of 125 mm.	61.60	6.61	407.18
SAN3.02	m	PVC downpipe of 80 mm.	36.00	6.01	216.36
SAN3.03	ud	Drum box in downpipe	12.00	45.08	540.96
SAN3.04	m	Gravelly drainage	61.60	3.01	185.42
Total chapter 03#					1,349.92
04# STRUCTURE					
EST4.02	m	Prefabricated purlin Precon I-819	924.00	3.88	3,585.12
EST4.05	m	Prefabricated beam Precon PV-80/7	4.80	64.91	311.57
EST4.11	ud	Prefabricated beam Precon PA-135/40, 18.5 m	5.00	1537.0	7,535.00
EST4.14	m	Load beam Precon C-3530	106.00	24.73	2,621.38
EST4.17	m	Prefabricated columns 30x30 4e16	36.00	39.07	1,406.52
EST4.18	m	Prefabricated columns 35x35 4e16	83.00	43.15	3,582.00
EST4.20	ud	Corbel in column	18.00	51.09	919.62
Total chapter 04#					19,831.21
05# ROOFING					
CUB5.01	m	Ridge cup ventilation of fibre cement	33.80	16.83	518.36
CUB5.02	m2	Corrugated fibre cement sheets	877.80	13.82	9,497.80
CUB5.03	m2	Translucent corrugated sheets	46.20	16.83	777.55
Total chapter 05#					10,793.71
06# WALLING					
CER6.01	m2	Concrete breeze blocks	301.00	16.92	5,092.92
Total chapter 06#					5,092.92
07# FLOORING					
SOL7.01	m2	Flooring of stone chips	876.00	4.10	3,591.60
SOL7.02	m2	Concrete flooring of 13 cm. HA-25/P/20/IIa	723.00	19.22	13,988.40
SOL7.03	m2	Concrete flooring of 23 cm. HA-25/P/20/IIa	156.00	21.04	3,282.24
Total chapter 07#					14,232.24
08# PLUMBING					
FON8.01	m	Low density polyethylene pipe	89.20	1.80	160.56
FON8.02	ud	Water Troughs	8.00	111.19	889.52
FON8.03	ud	Sphere valve	8.00	6.01	48.08
Total chapter 08#					1,098.16
09# ELECTRICITY					
ELE9.01	m	Copper nude cable 1x35	180.80	1.18	213.34
ELE9.02	ud	Earth leakage protection	2.00	21.78	43.56
ELE9.03	ud	Protection box and measure in polyester	1.00	40.60	40.60
ELE9.06	ud	Distribution board with capacity for 54 poles	1.00	61.99	61.99
ELE9.08	ud	Magnetothermal device ICP 4P	1.00	53.43	53.43
ELE9.09	ud	Circuit-breaker 32 A (III-N)	1.00	53.86	53.86
ELE9.11	ud	Residual current device 4P 40A, 30mA	2.00	73.67	147.34
ELE9.12	ud	Magnetothermal protection device 4P 10A	1.00	42.67	42.67
ELE9.13	ud	Magnetothermal protection device 2P 10A	4.00	20.07	80.28
ELE9.15	ud	Derivation box 100x100x50 mm.	4.00	3.62	14.48
ELE9.18	m	Tubo de protección rígido. Diámetro 25 mm	135.12	2.71	366.18
ELE9.22	m	Cable H07V-U 1x1.5 according to UNE 21031	514.80	0.29	149.29
ELE9.24	m	Cable RV-K 0.6/1 KV, 4x6 according UNE 21123	33.00	3.23	96.90
ELE9.25	ud	Industrial lamp 1x58 W. IP66/ c/I	23.00	58.21	1,342.83
Otros varios (5%)					126.41
Total chapter 09#					2,654.53
10# CLEANING EQUIPMENT					
LIM10.04	ud	Automatic scraper for 4 alleys of 3-4 m	1.00	12,140	12,140.00
LIM10.06	m	Central guide for automatic scraper	131.20	33.06	4,337.47
Total chapter 10#					16,477.47
11# INTERNAL DISTRIBUTION					
DIS11.01	ud	Headrail self-locking, hot-dip galvanized steel tubing	80.00	42.07	3,365.60
DIS11.02	ud	Hot-dip galvanized steel tubing dividers	80.00	48.08	3,846.40
Total chapter 11#					7,212.00
12# CARPENTRY					
CAR12.01	ud	Door of hot-dip steel sheet, 3030x3300 mm.	2.00	450.76	901.52
CAR12.02	ud	Door of hot-dip steel sheet, 3030x4300 mm.	2.00	564.95	1,129.90
CAR12.03	ud	Door of hot-dip steel sheet, 4530x4300 mm.	2.00	835.41	1,670.82
Total chapter 12#					3,702.24
Total budget ##					89,438.35

Sep	6.08	Between-column distances		
Ncu	80	Number of cows		
NF	4	Number of rows of stalls		
Acu =	1.25	Stall width		
Lcu=	2.5	Stall length		
Lco =	0.75	Feedspace width		
Apco>=	2.5	Transverse alley width		
Apra=	4	Feed alley width		
Aprp=	3	Freestall alley width		
Apra =	5.2	Width feed alley plus driveway		
Npc =	4	Transverse alley communicating		
Ep =	0.4	Column width		
Aext =	30.00	Exterior width		
Aint =	20.20	Interior width		
Lint =	30.00	Interior length		
Lext =	30.80	Exterior length		
dimensions (m)				
N°				
Foundations				
Lateral	a	b	h	N°
Interior	1.1	1.1	0.8	12
Gable end	1.1	1.1	0.5	4
Columns			N°	
Lateral	a	b	h	N°
Interior	0.30	0.30	3	12
Gable end	0.35	0.35	5	4
Brace beams			N°	
Lateral	a	b	h	N°
Interior	0.35	0.35	5.1	10
Gable end	0.35	0.35	50.6	10

GABLE END

SECTION

PLANT (example for N = 80)

Figure 4. Spreadsheet analysis of design T2 for an 80-cow barn.

Figure 5. Calculated costs per stall of the six designs considered, together with the equations of the corresponding fitted curves and their points of intersection.

With measurements and quantitative structural characteristics in hand, the corresponding construction work was analyzed into costing units for the purposes of cost estimation (Ramírez, 1997). Whenever possible, units and the corresponding unit costs were taken from available Spanish databases for estimating costs (Barrasa, 1999). For work for which no available data base featured an applicable costing unit, ad hoc

Figure 6. Calculated costs per square meter of barn of the six designs considered, together with the equations of the corresponding fitted curves and their points of intersection.

units were defined, cost estimates were obtained from a panel of 14 construction industry professionals, and the estimate nearest to the mean of the 14 was adopted as the unit cost. The cost information is based on prices in the year 2000.

A spreadsheet application was then written that, given one of the designs of Figure 2, calculates 1) the measurements of foundations and footings for given E_P and Sep , 2) unit costs for given N , and 3) total estimated cost for given N (Figure 4).

RESULTS AND DISCUSSION

Figure 5 shows the costs of designs T1 to T6 per stall for various values of N between 20 and 200 (depending on design), together with fitted curves of the form $Cost = aN^b$, the equations and coefficients of determination of these curves, and the values of N at which the curves intersect each other.

Figure 6 shows analogous data for the cost per square meter of barn. In both cases, costs naturally decrease as N increases due to the spreading of fixed costs among a larger number of stalls or over a larger surface area; the cost per stall of design T2, for example, is almost 60% less expensive for a 200-stall barn than for a 40-stall barn. The main fixed costs correspond to the scraper and the structure and fittings of the end walls. The scraper also contributes significantly to the differences in cost among the various designs, because the cost of the scraper depends on the number and surface area of the alleys to be cleaned. The costs of different designs for the same number of stalls differ by up to 25%, depending on the number of stalls (although costs per square meter differ by no more than 16%).

Although not addressed specifically in the current study, optimal housing designs for herds larger than 200 cows might differ from the alternatives examined herein.

CONCLUSIONS

From the results of the developed model, it may be concluded that preferred designs for farms with 60 to 200 cows are T2 (four rows of facing free stalls) or T4 (four rows of tail-to-tail free stalls), which have virtually the same costs, whereas for farms with fewer than 60 cows, the preferred design was T3 (two rows of tail-to-tail free stalls). In general, the results of the calculations must be integrated with other considerations in choosing a particular design. Lastly, total construction costs need to include items such as milking parlor or dung storage; without those a dairy housing system is not completely defined.

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