飼料工場 設置를 위한 所要資本 推定 模型

Mathematical Models of Capital Requirement For Feed Mills

朴 京 圭*· 丁 道 燮**
Park, Kyung Kyu · Chung, Do Sup

摘 要

配合飼料工場의 生産規模 및 生産飼料種類別 所要 投資 資本을 推定할 수 있는 모델을 開發하였다. 캔사스 주립대학교(Park, 1982)에서 開發된 配合飼料工場의 設計 모델을 利用하여 機械 및 備品값, 設置費用, 建築費用, 電氣器具 및 電氣施設費 등을 關聯業体의 도움을 얻어 分析하였으며, 모델에 適用된 工場의 規模는 10 ton/hr에서 40ton/hr이고, 工場對象은 養豚 및 養鷄用 飼料工場(1일 8시간 作業, 1일 16시간 作業)과 乳牛用 펠릿 飼料工場(1일 8시간 作業)이었다.

I. Introduction

A primary consideration for a future plant owner is the amount of capital investment required to build a plant since a major portion of its fixed cost arises from the investment cost. However, numerous factors are involved for plant investment cost. Major factors to be considered are the size of mill; the type of equipment and its intallation; the kinds and type of feed to be produced; the location of the plant to be built; land price; and the type of building and its construction cost.

All feed manufacturers do not have the same basic requirements nor do they have the same amount of capital requirement. Usually, the decision of the factors is a compromise between what the future owner believes is needed, and what the available capital will allow.

Vosloh (1968, 1976) reported on feed manufacturing cost and capital requirement. Schnake (1979) has studied the costs and capital requirements for pelleting the grain cust by stationary and portable plants.

An important question in the feed industry is what size and type of feed mill can be built to maximize the profit. In order to answer this question, a mathematical model for capital requirement is an indispensible, along with a labor requirement model, and an energy consumption model.

The objective of the study is to develop a mathematical model for capital requirements of feed mill based on the general feed mill model and output of computer program for feed mill design developed in Kansas State University (Park, 1982).

II. Methods and Assumptions

A swine and poultry feed mill and a complete pelleted dairy feed mill are selected for developing the mathematical model. The analyses for developing the mathematical model for capital requirement are made in terms of a capacity of feed mill which ranges from 10 ton/hr to 40 ton/hr and ratios of each type of finished feed production to total feed production.

*慶北大 農大 農工學科
**Kansas State University

Table 1. Operational designation used for variations in models

Type of feed	Ratio of finished feed type to total feed production								
	A	B	C	D	E	F	G	H	I
Mash bulk	1.0	0.5	–	–	–	–	0.5	0.25	–
Mash bagged	–	0.5	1.0	–	–	–	–	0.25	0.5
Pellet bulk	–	–	–	1.0	0.5	–	0.5	0.25	–
Pellet bagged	–	–	–	–	0.5	1.0	–	0.25	0.5

Operational designation for feed mills are presented in Table 1.

The cost functions considered in developing a mathematical model for capital requirement are:

1) Equipment costs
2) Installation costs
3) Building construction costs
4) Electric system equipment and installation costs

Note that all of these prices and costs are based on May, 1981.

A. Equipment

The number, sizes and types of equipment required in the model mill are obtained from the computer program for feed mill design (Park, 1982). The prices of equipment are collected from feed mill equipment manufacturers presented in Table 2. The equipments are divided into eight categories:

Table 2. Sources of system catalog and price quotation

Item	Company
Truck and rail receiving scale	Cardinal scale Mfg. Co.
Drag conveyor	Screw conveyor Corp. Sprout-Waldron Co.
Screw conveyor and feeder	Riley Equipment Co. Sprout-Waldron Co.
Bucket Elevator	Sprout-Waldron Co. Hays and Stoltz Ind.
Screening and grading equipment	Sprout-Waldron Co.
Turn-head distributor and Swing spout distributor	Hays and Stoltz Ind.
Diverter valve	Hays and Stoltz Ind.
Mixer	Hays and Stoltz Ind.
Mixer scale hopper, scale and control panel	Leaching Mfg. Co.
Hammermill and its system	Champion product Co.
Pellet mill and its system	Califonia Pellet Mill Co.
Inside working bin	Leach Mfg. Co.
Outside storage bin	Butler Co.
Liquid storage and handling system	Hays and Stoltz Ind. Viking Pump Co.
Boiler System	Superior Boiler Works Inc.
Bagging system	Union Camp Corp.
Dust collector	Champion Product Co.

1) Receiving equipment includes weighing, hoppers, conveyors, bucket elevators, cleaning and the other equipment for the handling the incoming materials from the receiving points to storage bin.

2) Storage equipment for outside bins consists of outside storage bins, conveyors, distributor and the other equipment for the handling and storage of the bulk ingredients from storage bin to inside working bins.

3) Work bins and other associated equipment include inside storage bins, and pellet mash bins, hammermill surge bins, screw feeders, scale hoppers, weighing and mixing control devices.

4) Hammermill equipment consists of a feeder conveyor, a hammermill, mechanical conveyors, bucket elevator, distributor and air scavanger filter.

5) Mixing equipment consists of a mixer, surge hoppers, conveyors, feed dresser, bucket elevator, distributor to bulk loadout bins or to the other mash bins.

6) Pelleting equipment includes surge bin, pellet mill, cooler, dust collector, crumbler, conveyor, bucket elevator, cleaner and distributor.

7) Bulk loadout and bagging equipment consists of finished feed bins, air cylinder gates, a conveyor, a pellet cleaner, a weighing, cleaning, a packing surge bin, a packing scale and sewing machines.

8) Miscellaneous equipment in the model include items not assignable to any particular cost center, such as a boiler, the liquid storage and handling system, an air compressor, a manlift, dust collectors and forklift trucks.

B. Installation and Shipping

The installation costs of equipment items for the model are assumed as 35% of the total equipment prices (Salisbury, 1981). Since the estimated equipment prices are based on F.O.B., 7% of the total equipment cost is assumed as shipping cost from equipment manufacturers to the construction site (Salisbury, 1981).

C. Land and Building Construction

Acreage requirements for the model mills are determined by the land occupied by the mill buildings plus adequate spaces for truck movement. The models are assumed to require a minimum of 2 acres for smaller mills and up to 4 acres for the larger mill (Vosloh, 1976). A number of variables in determining construction cost include: the location with reference to transporation: topography: and soil conditions of site: type and size of building constructed: building material used: and local building costs (Vosloh, 1976). Thus, all mills are located at fairly level sites, and to have rail and highway access. Soil conditions are assumed to satisfactorilly support building with normal concret footings. Also, several assumptions are made to estimate the building construction cost.

1) The plant building (Schultz, 1981).
   Concrete wall, 8 ft deep = 18.00 dollars/linear foot.
   Slab concrete = 1.5 dollars/ft
   First floor concrete = 5.0 dollars/ft^2
2) The warehouse, steel building = 12.7 dollars/ft^2 (Vosloh, 1976). 1/
3) The office = 36.5 dollars/ft^2 (Vosloh, 1976). 1/
4) Boiler shop and maintenance = 20.4 dollars/ft^2 (Vosloh, 1976). 1/
5) Rail side = 36.6 dollars/linear ft of track (Vosloh, 1976). 1/
6) Sand = 3 dollars/cu yard (Schultz, 1981).
7) Land Price = 13,200 dollars/acre (Vosloh, 1976). 1/

1/ Converted value based on May, 1981.

D. Electrical System Equipment and Installation

Based on the output of the computer program for feed mill design and its model (Park, 1982) the cost estimation of electrical system equipment and its installation is performed with the help of a commercial electric contract company (Machin, 1981). This estimation consists of electric motor wiring, building wiring, service system, V.G. feeder, pannel board, dry transformer, power factor correction capacitors, control wiring, and building transformer.

III. Capital Requirement for Feed Mills

A Equipment Cost

The swine and poultry feed mill and the complete pelleted dairy feed mill are analyzed for estimating the equipment cost by following the methods and assumptions described in previous sections.

a. Swine and poultry feed mill

Equipment costs for 1-shift operation/day mill and 2-shift operation/day are estimated separately since warehouse and storage capacity of a 2-shift operation mills are assumed to have double capacity of a 1-shift operation. The other equipment of 2-shift operation model mill are assumed to be the same as in a 1-shift operation mill. The results obtained are presented in Tables 3 and 4 as a function of size of mill and the ratio of each type of finished feed production to total feed production.

b. Complete pelleted dairy feed mill

Since the density of dairy feed product is much lower than that of the swine and poultry feed products, the size of equipment is larger than that of the swine and poultry feed mill. Also, the capital requirement for equipment is, in general, higher than that for the swine and poultry feed mill. The results obtained are presented in Table 5.

B. Land Cost and Building and Its Construction Cost

The capital requirement for land, for building, and for the construction are assumed to be the same as both the swine and poultry feed mill and the complete pelleted dairy feed mill. However, warehouse capacity of a 2-shift operation feed mill has double the capacity of a 1-shift operation feed mill. Based on the methods and assumption made in previous section, the results are obtained and presented in Tables 6 and 7.

C. Electrical System Equipment and Installation

Based on the methods and assumptions made in the previous section, the results are obtained and

Table 3. Equipment cost estimation of swine and poultry feed mill, 1-shift operation

Capacity, ton/day	Type of operation								
	A	B	C	D	E	F	G	H	I
	dollars								
80	747,212	838,328	819,636	877,735	980,351	950,159	852,476	943,952	924,900
140	850,037	952,653	933,469	1,119,051	1,221,667	1,202,463	980,470	1,083,086	1,063,902
200	973,686	1,087,402	1,079,151	1,300,425	1,300,425	1,406,293	1,136,294	1,250,420	1,242,162
260	1,077,262	1,201,881	1,193,613	1,408,675	1,606,291	1,597,023	1,344,999	1,470,615	1,461,347
320	1,133,976	1,259,592	1,262,234	1,680,138	1,850,799	1,808,531	1,402,420	1,528,036	1,530,268

Table 4. Equipment cost estimation of swine and poultry feed poultry feed mill, 2-shift operation

Capacity, ton/day	Type of operation								
	A	B	C	D	E	F	G	H	I
	dollars								
160	841,858	932,974	914,282	972,382	1,075,197	1,044,805	947,122	1,038,598	1,019,546
280	1,001,320	1,103,936	1,084,752	1,270,334	1,372,950	1,353,766	1,131,753	1,234,369	1,215,185
400	1,214,882	1,328,598	1,320,437	1,541,621	1,655,737	1,647,489	1,377,490	1,491,616	1,483,358
520	1,400,931	1,524,547	1,517,279	1,804,341	1,929,957	1,900,689	1,668,665	1,794,281	1,785,023
640	1,503,982	1,629,598	1,632,330	2,050,144	2,175,805	2,178,537	1,772,426	1,898,042	1,900,274

Table 5. Equipment cost estimation of pelleted dairy feed mill, 1-shift operation

Capacity ton/day	Type of operation D	E	F
	dollars		
80	974, 265	1, 056, 418	1, 046, 579
140	1, 244, 774	1, 347, 391	1, 316, 707
200	1, 372, 521	1, 485, 637	1, 477, 389
260	1, 601, 476	1, 727, 092	1, 717, 824
320	1, 720, 900	1, 846, 516,	1, 837, 248

presented in Table 8.

D. Grand Total Cost for Capital Requirement

In developing a mathematical model for capital requirement, two quantities, namely, equipment cost and construction costs were analyzed separately because of a probable difference in inflation rate between them. However, in the past ten years both have shown similar changes in their price index (USDC, 1981). Thus, in this model, the two terms are

Table 6. Cost for land, building and construction, 1-shift operation

Capacity, ton/day	Type of operation A	B	C	D	E	F	G	H	I
	dollars								
80	196, 977	245, 279	292, 218	196, 977	245, 279	292, 218	196, 977	245, 279	292, 218
140	232, 560	326, 207	405, 080	232, 560	326, 207	405, 080	232, 560	326, 207	405, 080
200	277, 129	409, 539	542, 129	277, 129	409, 539	542, 129	277, 129	409, 539	542, 129
260	299, 521	471, 937	644, 578	299, 521	471, 937	644, 978	299, 521	471, 937	644, 578
320	323, 229	535, 476	746, 656	323, 229	535, 476	746, 656	323, 229	535, 476,	746, 656

Table 7. Cost for land, building and construction, 2-shift operation

Capacity, ton/day	Type of operation A	B	C	D	E	F	G	H	I
	dollars								
160	203, 635	289, 540	380, 738	203, 635	289, 540	308, 738	203, 635	289, 540	308, 738
280	255, 187	398, 203	549, 072	255, 187	398, 203	549, 072	255, 187	398, 203	549, 072
400	289, 738	534, 333	791, 716	289, 738	534, 333	791, 716	289, 738	534, 333	791, 716
520	315, 490	634, 443	969, 589	315, 490	634, 443	969, 589	315, 490	634, 443	969, 589
640	344, 787	743, 323	1, 144, 349	344, 787	734, 323	1, 144, 349	344, 787	734, 323	1, 144, 349

Table 8. Cost for electrical system equipment and its installation

Capacity, ton/day	Type of operation A	B	C	D	E	F	G	H	I
	dollars								
80	147, 359	155, 080	162, 472	169, 377	176, 822	184, 273	155, 238	162, 742	170, 134
140	152, 593	167, 581	179, 341	192, 767	207, 757	219, 517	175, 174	190, 142	201, 902
200	165, 697	192, 783	206, 447	209, 926	237, 030	205, 694	189, 663	210, 435	230, 431
260	168, 690	195, 954	222, 138	221, 297	247, 401	273, 945	206, 606	233, 150	259, 694
320	174, 773	239, 901	233, 020	265, 668	247, 401	298, 148	222, 489	255, 137	287, 617

directly combined in order to make a simpler model.

The grand total capital requirements for 105 model mills are estimated by combining the equipment cost, land and building construction cost, equipment shipping and installation cost and electrical system equipment and installation costs (Park, 1982).

The results obtained are presented in Tables 9, 10, and 11 as functions of the size of mill and ratio of each type of finished feed to total feed production.

IV. Mathematical Model for Captial Requirements

Three mathematical models are developed for capital requirement of the model mill by using SAS program as function of size of feed mill and the fractions of each type of finished feed production. Data present in Tables 9, 10, and 11 are used for developing the mathematical models.

Table 9. Grand total capital requitement of swine and poultry feed mill, 1-shift operation

Capacity, ton/day	Type of operation								
	A	B	C	D	E	F	G	H	I
	dollars/ton								
80	17,567	19,885	20,027	20,159	22,644	22,821	19,534	21,855	22,196
140	11,373	13,190	13,642	14,388	16,205	16,655	12,857	14,764	15,127
200	9,127	10,732	11,405	11,668	13,276	13,949	10,402	11,978	12,682
260	7,685	9,133	9,853	10,090	11,540	12,255	9,292	10,744	11,459
320	6,588	8,012	8,663	9,296	10,460	11,290	7,298	9,251	10,023

Table 10. Grand total capital requirement of swine and poultry feed mill, 2-shift operation

Capacity ton/day	Type of operation								
	A	B	C	D	E	F	G	H	I
	dollars/ton								
160	9,665	11,059	11,509	10,961	12,458	12,354	10,649	12,044	12,041
280	6,534	7,619	8,103	7,423	9,127	9,610	7,277	8,361	8,845
400	5,451	6,534	7,183	6,722	7,806	8,455	6,809	7,157	7,821
520	4,756	5,762	6,435	5,960	6,966	7,582	5,561	6,568	7,238
640	4,149	5,138	5,774	5,503	6,362	7,088	4,819	5,757	6,454

Table 11. Grand total capital requirement of complete pelleted dairy feed mill, 1-shift operation

Capacity, ton/day	Type of operation		
	D	E	F
	dollars/ton		
80	21,873	24,028	24,533
140	15,664	17,480	17,817
200	12,180	13,781	14,454
260	10,750	12,199	12,915
320	9,477	10,640	11,418

a. Model for the swine and poultry feed mill, 1-shift operation

$$CI_{spl} = \gamma\{7998 - 5160xR_1 - 2735xR_2 - 2488xR_3 + \{1196463 + 380774xR_1xR_2 + 306220xR_3(1 - R_3)\}/X] \cdots\cdots (1)$$

$$R^2 = 0.995$$

where

γ = inflation rate of industrial commodities

R_1 = fraction of mash bulk feed production, decimal

R_2 = fraction of mash bagged feed production,

decimal

R_3 = fraction of pellet bulk feed production, decimal

R_4 = fraction of pellet bagged feed production, decimal

CI_{spl} = capital requirement for swine and poultry feed mill, 1-shift operation, dollars/ton.

b. Model for the swine and poultry feed mill, 2-shift operation

$$CI_{sp2} = \gamma[5430 - 3013xR_1 - 1246xR_2 - 1780xR_3 \{1152517 + 383732xR_1xR_2 + 413135xR_3(1 - R_3)\}/X], \quad R^2 = 0.995 \quad \text{..... (2)}$$

where

CI_{sp2} = capital requirement for swine and poultry feed mill, 2-shift operation, dollars/ton

c. Model for the complete pelleted dairy feed mill, 1-shift operation

$$C_d = \gamma[7748 - 2239xR_3 + \{1242539 + 310336xR_3(1 - R_3)\}/X], \quad R^2 = 0.994 \quad \text{..... (3)}$$

where

C_d = capital requirement for complete pelleted dairy feed mill, dollars/ton.

Note that γ is the inflation rate of industrial commodities, between May 1981 and the time when these models are being used. All of the above models are developed, based on May 1981 prices and costs. The results of the mathematical models expressed in Equation 1, 2, and 3 are plotted as a function of plant capacity in Figures 1, 2, and 3. Note that B, D, E, F, and H in the figures are the ratio of each type of finished feed to total feed production (see Table 1).

V. Discussion of the Results

Tables 9, 10, and 11 and Figures 1, 2, and 3 show that plant capacity is the most significant factor affecting the capital requirement of the feed

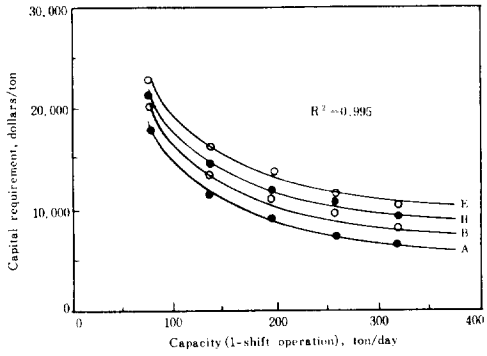

Fig. 1. Capital requirement for swine and poultry feed mill, 1-shift

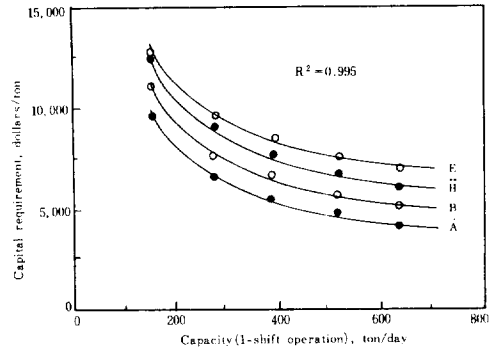

Fig. 2. Capital requirement for swine and poultry feed mill, 2-shift

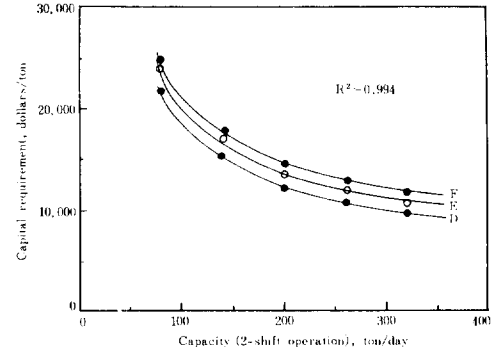

Fig. 3. Capital requirement for complete pelleted dairy feed mill, 1-shift

mill model. The pellet system is the next factor which influences the capital requirement. Also, the system to produce the bagged type feed is the another factor to increase the capital requirement. Capital requirement of a 2-shift operation feed mill is approximately half that of a 1-shift operation feed mill.

The dairy feed mill requires a slightly higher capital requirement than swine and poultry feed mill because its equipment is more bulky than the swine and poultry equipment.

The equipment cost occupies from 45% of the total capital requirement. The construction cost comprizes of only 15% to 20% of the total capital investment. It should be noted that costs of working bins and storage bins are considered as equipment costs. Also, equipment shipping and installation costs and electrical system equipment and installation cost comprize of from 18% to 22% and from 8% to 10% of the total capital requirement, respectively.

It is not desirable to use these models when concrete storage bins are used since storage bins and working bins are assumed to be of steel construction.

Though the models are developed, based on May 1981 prices and costs, the coefficients for the inflation rate of industrial commodities enable them not only to be used in the future cost but also to estimate past cost.

Since correlation coefficients of the Equations 1, 2, and 3 for capital requirement of the 1-shft, 2-shift operating swine and poultry feed mill and completely pelleted dairy feed mill are 0.995, 0.994 0.995, respectively, they can be well used to predict the capital requirements for various sizes and fractions of finished feed production.

VI. Summary and Conclusions

A swine and poultry feed mill and a complete pelleted dairy feed mill are selected to develop the mathematical model for capital requirement. The analyses for capital investments are made in terms of a capacity of feed mill which ranges from 10 ton/hr to 40 ton/hr and fractions of finished feed production.

The total 105 model plants are analyzed for developing capital requirements. The capital requirements of each model are divided in equipment cost, equipment shipping and installation cost, land and building construction cost, and electrical system equipment and installation cost.

The data for the size and dimension of equipment and building are obtained from a computer program for feed mill design and data for prices and costs of equipment, installation and construction are obtained from commercial feed equipment manufacturers, a construction company and a commercial electrical contracting company. Based on the analyses of these data, equipment cost, equipment shipping and installation cost, land and building construction cost and electrical system equipment and installation cost of 105 model plants are analyzed. By combining these cost terms and by using SAS program, three mathematical models for capital requirement are developed as function of size of mill and fractions of finished feed production. From the results of the study, the following conclusions are drawn:

1. Correlation coefficients of capital requirement model for the swine and poultry feed mill operating 1-shift and 2-shift and complete pelleted dairy feed mill operating 1-shift and 2-shift and complete pelleted dairy feed mill are 0.995, 0.994 and 0.995, respectively. Therefore, the models can be well used in estimating capital requirement for various sizes and fractions of finished feed production.

2. The most significant factor affecting the capital requirement is the plant capacity and the next factor is the pellet system. Also, the system producing bagged feed is another factor increasing capital requirements.

3. The equipment cost accounts for from 45% to 53% of the total capital requirement. The construction cost comprize 15% to 20% of the total capital investment. Also, equipment shipping and installation cost and electrical system equipment and installation costs comprize 18% to 22%, and 8% to

10% of the total capital investment, respectively.

4. The capital requirements for a model plant producing only pelleted bagged feed is from 30% to 80% higher than that of plant producing mash bulk only depending on the size of plant.

5. Depending on the size of plant, the capital requirements for a complete pelleted dairy feed mill are higher than that for a swine and poultry feed mill provided that the conditions are the same.

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學 會 廣 告

◎ ASPAC(Asian and Pacific Council) 세미나 開催

本 學會에서는 ASPAC/FFTC(Food and Fertilizer Technology Center)와 共同으로 小農을 위한 效率的인 營農機械化에 관한 세미나를 아래와 같이 開催하오니 會員 여러분의 많은 參與를 바랍니다.

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2. 場 所 : 서울特別市 冠岳區 新林洞 山56－1
   서울大學校 敎授會館
3. 세미나 內容 : 本 學會誌 後面廣告 參照